Flood Mitigation Report
East Branch Delaware River
SD 060

Delaware County, New York
January 2021

This document was prepared for the New York State Department of Environmental Conservation, in cooperation with the New York State Office of General Services.

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MMI #7160-01-04

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ABBREVIATIONS/ACRONYMS

BFE	Base Flood Elevation
CFS	Cubic Feet per Second
CMP	Corrugated Metal Pipe
CR	County Route
CRRA	Community Risk and Resiliency Act
CWC	Catskill Watershed Corporation
DCSWCD	Delaware County Soil and Water Conservation District
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FHMIP	Flood Hazard Mitigation Implementation Program
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FPMS	Floodplain Management Services Program
GIS	Geographic Information System
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HMA	Hazard Mitigation Assistance
HMGP	Hazard Mitigation Grant Program
HMP	Hazard Mitigation Plan
HSG	Hydrologic Soil Group
LiDAR	Light Detection and Ranging
MMI	Milone & MacBroom, Inc.
NFIP	National Flood Insurance Program
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOT	New York State Department of Transportation
NYSOGS	New York State Office of General Services

RFC	Repetitive Flood Claims
SFHA	Special Flood Hazard Area
SRL	Severe Repetitive Loss
TS	Trout Spawning
USACE	United States Army Corps of Engineers
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey

1.0 INTRODUCTION

1.1 Project Background and Overview

The East Branch of the Delaware River (EBDR) originates near the hamlet of Grand Gorge in Delaware County and flows south and west through the towns of Roxbury, Halcottsville, and Margaretville before entering the Pepacton Reservoir, which is operated by the New York City Department of Environmental Protection (NYCDEP) as part of the west-of-Hudson water supply system for New York City. Downstream of Pepacton Reservoir, the EBDR flows southwestward through the towns of Colchester and Hancock and joins with the West Branch of the Delaware River (WBDR) in the village of Hancock, to form the Delaware River along the New York/Pennsylvania state line.

Historically, flooding has been the greatest threat from natural disasters in Delaware County. Recent widespread flooding in the EBDR valley has occurred in 2011, 2007, 2006, 2005, 2004, and 1996, although severe localized flooding is a relatively frequent occurrence on tributary streams in the basin. This study focuses on the tailwater section of the EBDR, which extends 29 river miles from the outlet of the Pepacton Reservoir, downstream to its confluence with the WBDR in Hancock. Tailwater refers to waters located downstream of a hydraulic structure, in this case the dam at Pepacton Reservoir.

This work is a component of the Resilient New York Program, an initiative of the New York State Department of Environmental Conservation (NYSDEC), contracted through the New York State Office of General Services (NYSOGS). The goal of the Resilient New York Program is to make New York State more resilient to flooding and climate change. Through the program, flood studies are being conducted across the state, resulting in the development of flood and ice jam hazard mitigation alternatives to help guide implementation of mitigation projects.

This report begins with an overview of the EBDR channel and watershed, summarizes the history of flooding, and identifies flood-prone communities and High Risk Areas (HRA) along the EBDR. An analysis of flood mitigation considerations within each flood-prone community is undertaken. Factors with the potential to influence more than one EBDR community, such as the attenuating effect of the Pepacton Reservoir on downstream peak flows and the behavior of channel sediment, are also evaluated and discussed. Flood mitigation recommendations are provided either as community-specific recommendations or as overarching recommendations that apply to the entire EBDR watershed or stream corridor. For each flood-prone community, a relocation master plan is provided. The relocation plans are intended to be used on a voluntary basis by the county, municipalities, and by individual property owners to guide potential relocation efforts out of and away from flood-prone areas. An emphasis was placed on locating suitable sites within the same communities. Flood mitigation scenarios such as levee enhancement, sediment management, floodplain enhancement and channel restoration, road closures, and replacement of undersized bridges are investigated and are recommended where appropriate.

1.2 Terminology

The East Branch of the Delaware River is abbreviated throughout this report as the EBDR. The West Branch of the Delaware River is similarly abbreviated as the WBDR.

In this report, all references to right bank and left bank refer to "river right" and "river left," meaning the orientation assumes that the reader is standing in the river, looking downstream.

In this report and associated mapping, stream stationing is used as an address to identify specific points along the watercourse. Stationing is measured in miles and begins at the confluence of the EBDR and WBDR at station 0.0 and continues upstream to STA 33.4 at the Pepacton Reservoir. As an example, the Route 28 bridge over the EBDR in Fish's Eddy is located at approximately STA 11.3, meaning that it is 11.3 miles upstream of the confluence in Hancock.

The Federal Emergency Management Agency (FEMA) is an agency of the United States Department of Homeland Security. In order to provide a common standard, FEMA's National Flood Insurance Program (NFIP) has adopted a baseline probability called the base flood. The base flood has a 1 percent (one in 100) chance of occurring in any given year, and the base flood elevation (BFE) is the level floodwaters are expected to reach in this event. For the purpose of this report, the 1 percent annual chance flood is also referred to as the 100-year flood. Other recurrence probabilities used in this report include the 2-year flood event (50 percent annual chance flood), the 10-year flood event (10 percent annual chance flood), the 25-year flood event (4 percent annual chance flood), the 50-year flood event (2 percent annual chance flood), and the 500-year flood event (0.2 percent annual chance flood).

The Special Flood Hazard Area (SFHA) is the area inundated by flooding during the 100-year flood event. Within the project area, FEMA has developed Flood Insurance Rate Mapping (FIRM), which indicates the location of the SFHA along the EBDR and several of its tributaries.

2.0 DATA COLLECTION

Data were gathered from various sources related to the hydrology and hydraulics of the EBDR and its tributaries, EBDR watershed characteristics, recent and historical flooding in the affected communities, and factors that may contribute to additional flood hazards.

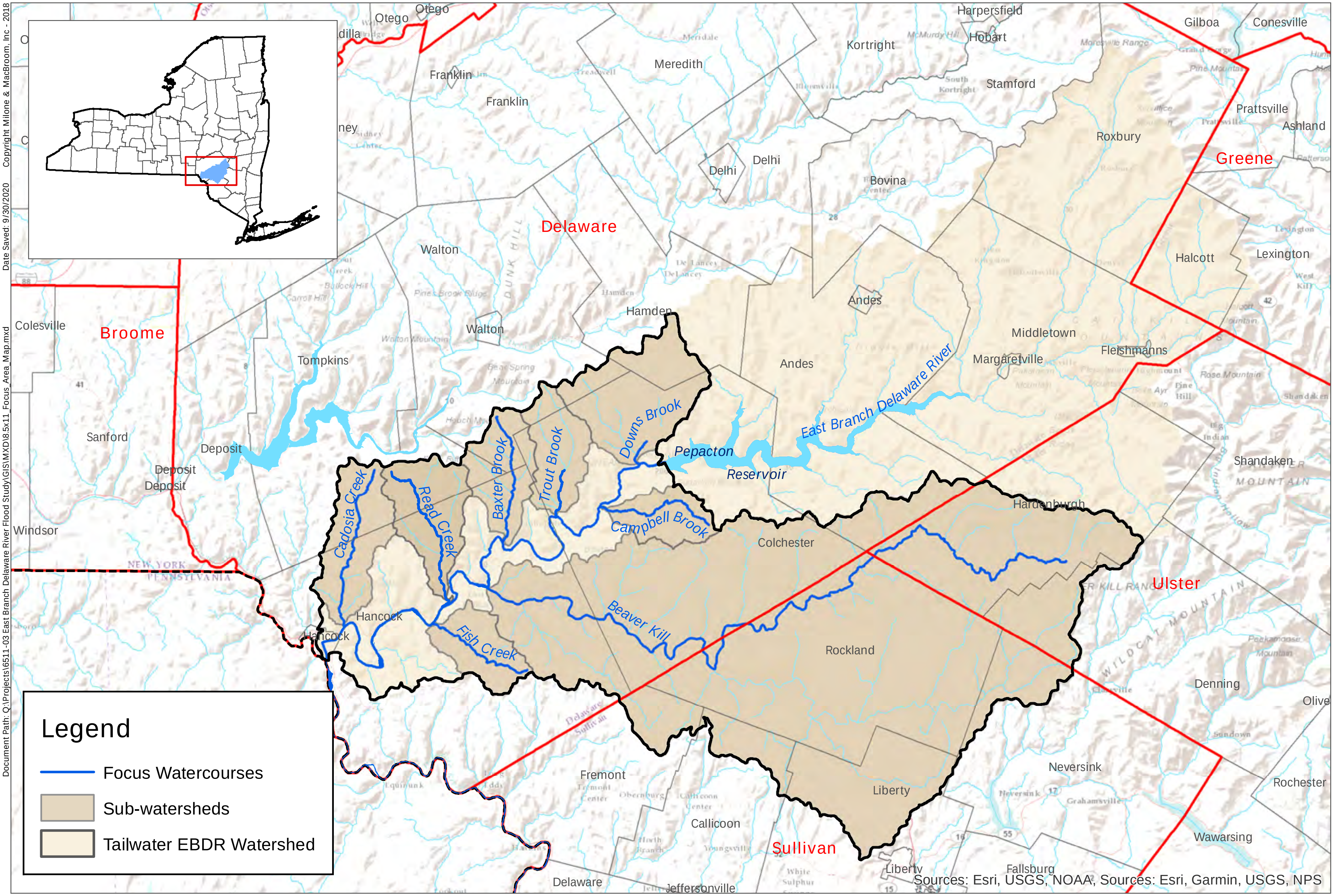
2.1 EBDR Watershed Characteristics

The EBDR watershed falls within the Northern Appalachian Plateau physiographic region of New York State. The watershed flows in a southwesterly direction, draining southern Delaware County, northern Sullivan County, and a portion of western Ulster County, including part of the Catskill Mountains. The entire watershed is underlain by Devonian clastic sedimentary bedrock, predominantly composed of sandstones, shales, and conglomerates. The bedrock geology has been mapped as the Upper Walton Formation in the valleys while the ridges and peaks are predominantly mapped as the Honesdale Formation. The Slide Mountain formation lies between the two. All three belong to the West Falls Group. The Middle-Upper Devonian Oneonta Formation and other constituents of the Genessee Group are encountered farther upstream in the valley. Areas of shallow or exposed bedrock occur at higher elevations. Surficial materials consist primarily of glacial drift, including till, outwash, and periglacial deposits, with alluvial and semi-alluvial secondary deposits of drift material in the valley bottoms.

The EBDR watershed, when measured at its confluence with the WBDR, is 841 square miles in size. An area of 371 square miles, or 44 percent of the EBDR watershed, is located upstream of the dam at the Pepacton Reservoir while the remaining 470 square miles, or 56 percent, is located downstream of the dam. Table 2-1 lists significant tributaries to the tailwater section of the EBDR, in order from upstream to downstream, along with the watershed size of each tributary. The largest tributary to the tailwater section of the EBDR is the Beaver Kill, with a watershed area of nearly 300 square miles. Figure 2-1 is a watershed map of the EBDR with the tailwater section highlighted.

TABLE 2-1
Subwatersheds within the Tailwater Section of the EBDR Watershed

EBDR Tributary	Sub-watershed Size (square miles)
Downs Brook	27.1
Campbell Brook	9.8
Trout Brook	13.1
Baxter Brook	14.3
Beaver Kill	299.0
Read Creek	17.2
Fish Creek	11.2
Cadosia Creek	18.0



EBDR FOCUS WATERSHEDS

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 2-1

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During a rainfall event, the proportion of rainfall that runs off directly into rivers and streams or that infiltrates into the ground is greatly influenced by the composition of soils within a watershed. Soils are assigned a hydrologic soil group (HSG) identifier, which is a measure of the infiltration capacity of the soil. These are ranked A through D. An HSG A soil is often very sandy, with a high infiltration capacity and a low tendency for runoff except in the most intense rainfall events; a D-ranked soil often has a high silt or clay content or is very shallow to bedrock and does not absorb much stormwater, which instead is prone to runoff even in small storms. A classification of B/D indicates that when dry the soil exhibits the properties of a B soil, but when saturated, it has the qualities of a D soil. Over 80 percent of the mapped soils in the EBDR watershed are classified as HSG C, C/D, or D, indicating a low capacity for infiltration and a high tendency for runoff (Figure 2-2). This contributes to flash flooding in the watershed as rainfall runoff moves swiftly into streams rather than gradually seeping through the soils. This is mitigated to some degree by the large areas of forest in the watershed, which tend to encourage infiltration and reduce runoff.

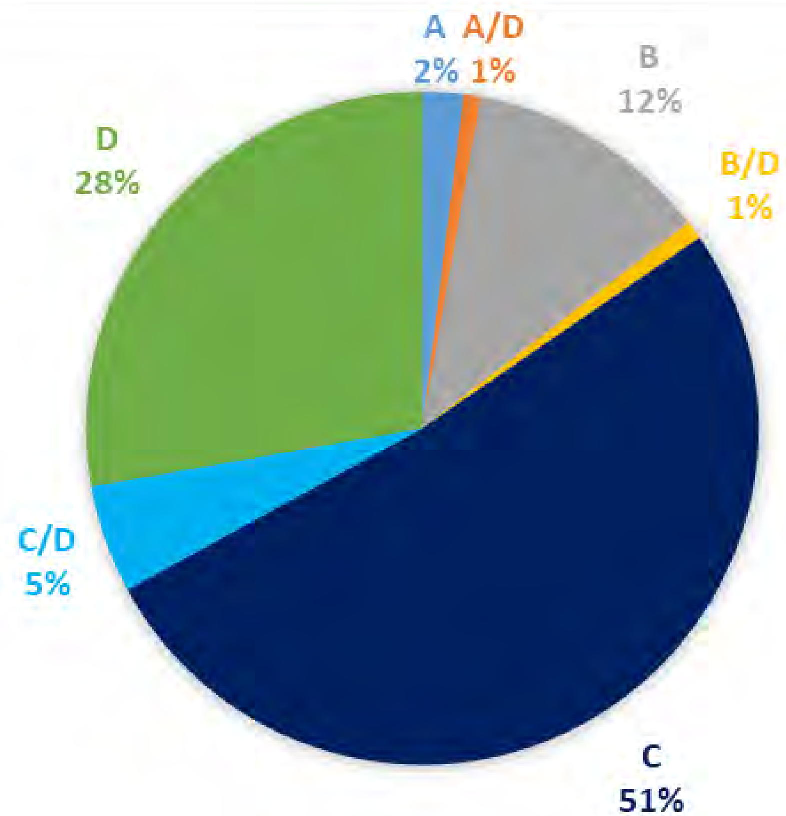

Figure 2-2: Hydrologic Grouping of Soils within the EBDR Watershed

Land cover also influences the runoff characteristics of a watershed. Land cover within the EBDR watershed can be characterized using the 2016 Multi-Resolution Land Characteristics National Land Cover Database for Southeast New York State and is shown graphically in Figure 2-3. Forested land consists of deciduous, coniferous, and mixed forest types and makes up 88 percent of the land cover in the watershed. Agricultural lands including hay, pasture, and cultivated crops make up 5 percent. Developed land represents 4 percent of the land cover. The remaining 3 percent of the land cover consists of grassland, shrubland, wetlands, open water, and barren land.

Wetland cover was also examined using information available from the U.S. Fish and Wildlife Services' National Wetlands Inventory (NWI). The NWI indicates that there are 13,381 acres of wetlands in the EBDR watershed, or approximately 2.5 percent of the watershed. This amount is consistent with the estimate based on land cover and includes the following types of wetland habitats: freshwater forest/shrub wetland, freshwater emergent wetland, freshwater pond, lake (reservoirs), riverine, and other wetland types. It is estimated that since colonial times, approximately 50 to 60 percent of the wetlands in the state of New York have been lost through draining, filling, and other types of alteration. In the Upper Delaware River basin, some wetland fill was composed of quarry waste and rock dust produced by the bluestone industry.

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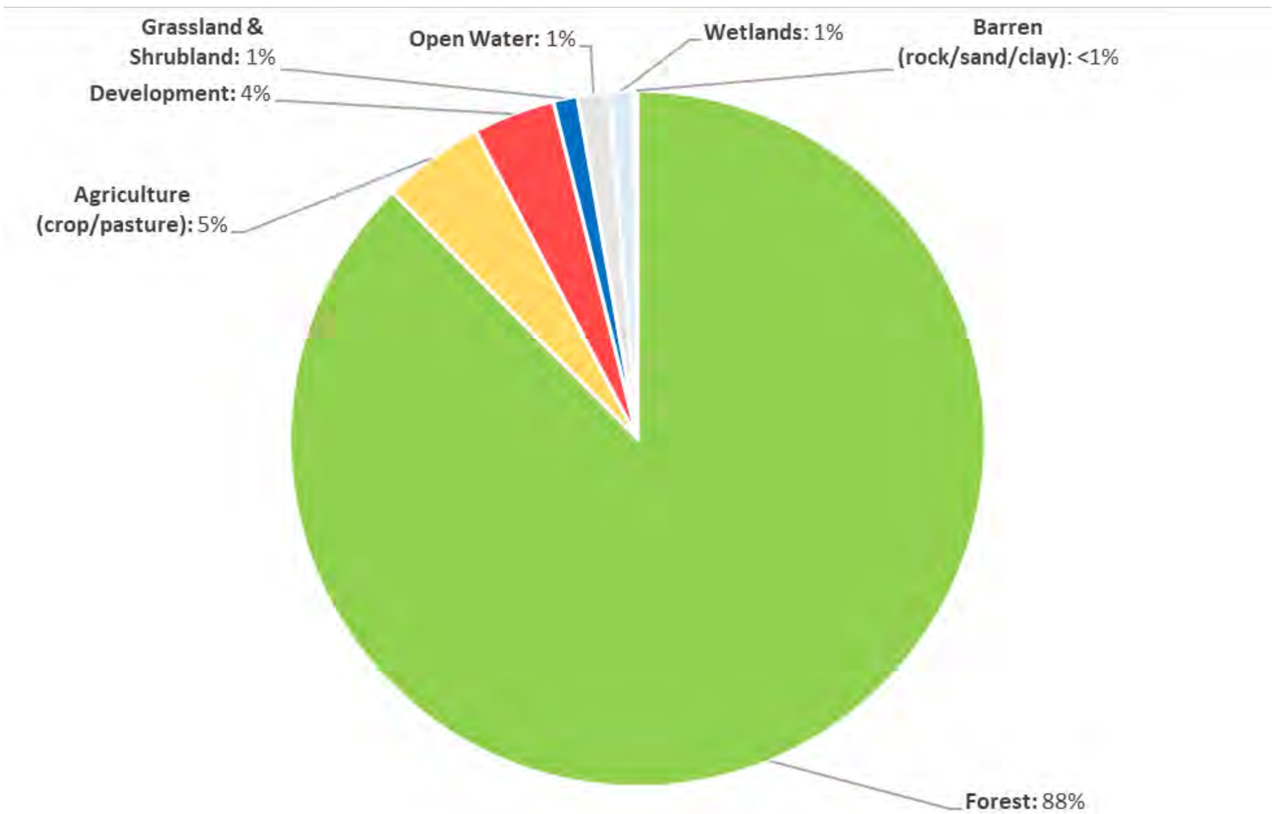


Figure 2-3: Land Cover within the EBDR Watershed

2.2 EBDR Watercourse

The EBDR flows through a confined valley, which was scoured by glaciers during the Pleistocene, then partially refilled with glacial drift and meltwater outwash deposits during the late Pleistocene and early Holocene glacial retreat. A critical consequence is that the active alluvial regime of the EBDR exists within a valley that has primarily been shaped by glacial processes. The EBDR and its tributaries are actively resculpting the landscape into a balance with the fluvial morphological processes that now dominate, a progression that occurs over millennial timescales and has yet to reach an equilibrium. In recent centuries, widespread and extensive anthropogenic activity has also shaped the EBDR, its tributaries, and their valleys and floodplains. These modifications have taken place within the context of a highly active, unstable morphological regime and often oppose the river's natural evolution. Such modifications therefore require frequent maintenance, are rarely permanent, and foster the especially severe flooding damages that can occur when the streams undergo fluvial adjustment, either in profile, planform, or both.

The active alluvial regime of the EBDR exists within a valley that has primarily been shaped by glacial processes. The EBDR and its tributaries are actively resculpting the landscape into a balance with the fluvial morphological processes that now dominate, a progression that occurs over millennial timescales and has yet to reach an equilibrium.

The width of the EBDR valley bottom ranges from a maximum of approximately 2,000 feet near Downsville to no more than a few hundred feet at several points where the channel occupies the full valley width. The channel is broad and shallow with a flat bottom, which is typical of aggrading channels. Sediment bars have formed at all major confluences with tributaries to the EBDR. This is typical of steep mountain streams entering flatter main stems. Figure 2-4 shows the EBDR valley in topographic relief.

The EBDR channel between Pepacton Reservoir and Hancock has a relatively mild slope, averaging 0.12 percent, or 6.3 feet per mile. Between Downsville and Hancock, a number of steep-gradient tributaries drain into the EBDR. These tributaries have a cobble or boulder substrate and, while small in size, comprise a large percentage of the cumulative length of the EBDR watershed stream network. These tributaries can act as sediment and debris reservoirs wherein coarse sediment and wood are episodically transported to the EBDR channel through erosion and bank failures. These processes can be especially dramatic during flood events. Figure 2-5 depicts the longitudinal profile of the low-gradient EBDR along with the profiles of several steep-gradient tributaries. Encroaching development and infrastructure are susceptible to damage by flooding on the EBDR as well as these dynamic, highly energetic tributaries.

Stream order provides a measure of the relative size of streams by assigning a numeric order to each stream in a stream network. The smallest tributaries are designated as first-order streams, and the designation increases as tributaries join. The EBDR from Margaretville downstream to Hancock can be characterized as a sixth-order stream while the EBDR upstream of Margaretville and larger EBDR tributaries such as the Platte Kill, Bush Kill, and Beaver Kill are fifth order. Examples of fourth-order streams include Dry Brook, the lower section of Downs Brook, and Cadosia Creek. Third-order stream examples include Campbell Creek, Baxter Brook, and Fish Creek. Many of the second- and first-order streams are unnamed. Figure 2-6 is a map depicting stream order in the EBDR watershed.

Characteristics of each order of stream (total length, average slope, and percentage of overall stream network) are summarized in Table 2-2. First-, second-, and third-order streams account for most of the overall stream length within the EBDR watershed (86 percent) and are much steeper in slope than fourth-, fifth-, and sixth-order streams.

Table 2-2 compares channel slope by stream order upstream and downstream of Pepacton Reservoir. Channel slopes are generally somewhat steeper upstream of the reservoir, especially the first- through fourth-order streams. Table 2-3 provides a comparison of channel slope by stream order in the EBDR watershed above and below the Pepacton Reservoir.

TABLE 2-2
Stream Order Characteristics in the EBDR Watershed

Stream Order	Total Length (miles)	Percentage of Overall Network Length (%)	Average Slope (%)
1st	920.0	53.6	8.0
2nd	363.2	21.2	5.7
3rd	192.0	11.2	2.6
4th	120.8	7.0	1.3
5th	57.6	3.4	0.5
6th	61.6	3.6	0.2
Total	**1,715.2**	**100**	

TABLE 2-3
Comparison of Channel Slope by Stream Order Above and Below Pepacton Reservoir

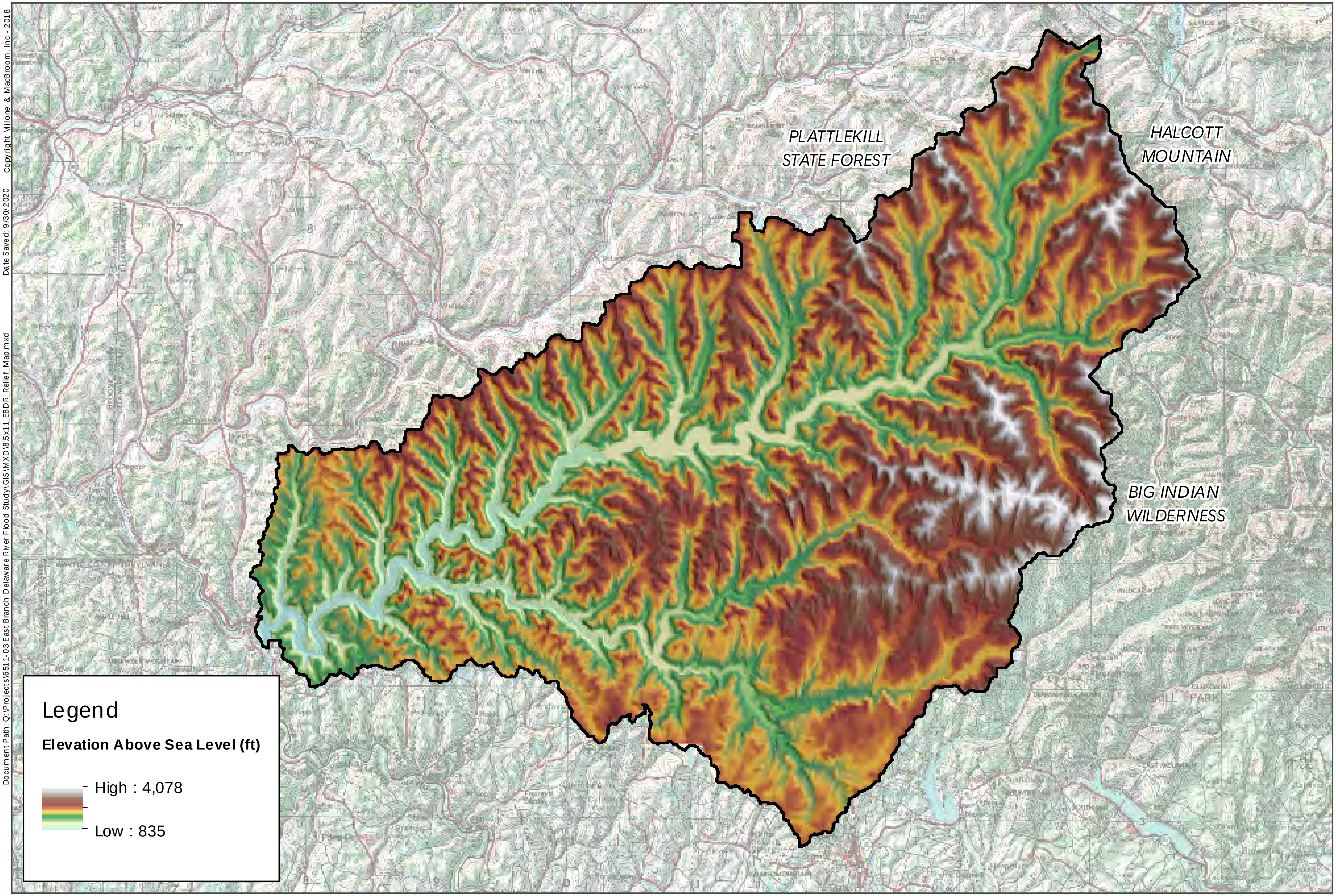
Stream Order	Average Slope Above Pepacton Reservoir (%)	Average Slope Below Pepacton Reservoir (%)
1st	8.5	6.6
2nd	6.5	3.8
3rd	2.7	2.2
4th	1.4	1.0
5th	0.5	0.5
6th	0.2	0.1

Fifteen bridges span the EBDR between the Pepacton Reservoir and the confluence with the WBDR in Hancock. These vary in age by over a century and represent a variety of construction styles, as listed in Table 2-4. While most of the bridges span the estimated bankfull width of the channel, some, such as the Harvard Road bridge, the Corbett Road bridge, and the Route 30 bridge in Downsville, do not.

TABLE 2-4
Bridges Spanning the EBDR between Hancock and the Pepacton Reservoir

Road	Location	River Station (miles)	NBI BIN	Year Constructed	Bridge Condition	Span (ft) (number of spans)	Rise Above Thalweg (feet)	Bankfull Width* (feet)
NYSW Railway	Hancock	1.1				338 (2)	28	278
Route 97	Hancock	1.2	1035490	2005	Good	455.1 (3)	26.2	278
Route 28	Fish's Eddy	11.3	3352620	1901	Fair	440 (3)	28.5	344
Route 17 Eastbound	Between Fish's Eddy and East Branch	13.4	1013422	1961	Fair	524 (5)	33.9	339
Route 17 Westbound		13.4	1013421	1961	Fair	524 (5)	33.9	339
Route 17 Westbound		14.9	1013431	1961	Fair	725.1 (9)	26.1	338
Route 17 Eastbound		14.9	1013432	1961	Fair	725.1 (9)	26.1	338
Old Route 17	East Branch	16.2	1061170	2011	Good	381.9 (3)	28.8	258
Route 17 Eastbound	East Branch	16.3	1013452	1961	Fair	583 (5)	50.2	258
Route 17 Westbound	East Branch	16.3	1013451	1961	Fair	583 (5)	50.2	258
Harvard Road	Harvard	19.6	-			223 (2)	25.9	252
River Road	Shinhopple	25.7	3352030	1992	Good	255.9 (2)	15.9	245
Corbett Road	Corbett	29.2	3352060	1926	Fair	212.9 (Main span + approach span)	27.5	241
Downsville Covered Bridge	Downsville	32.6	3352070	1857	Good	266.1 (2)	13.8	229
Route 30	Downsville	33.1	1020790	2017	Fair	170.9 (1)	14.5	229

* Estimated bankfull width per USGS SIR 2009-5144



EBDR RELIEF MAP

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 2-4

0 2 4 6 8
Miles
1 in = 6 miles

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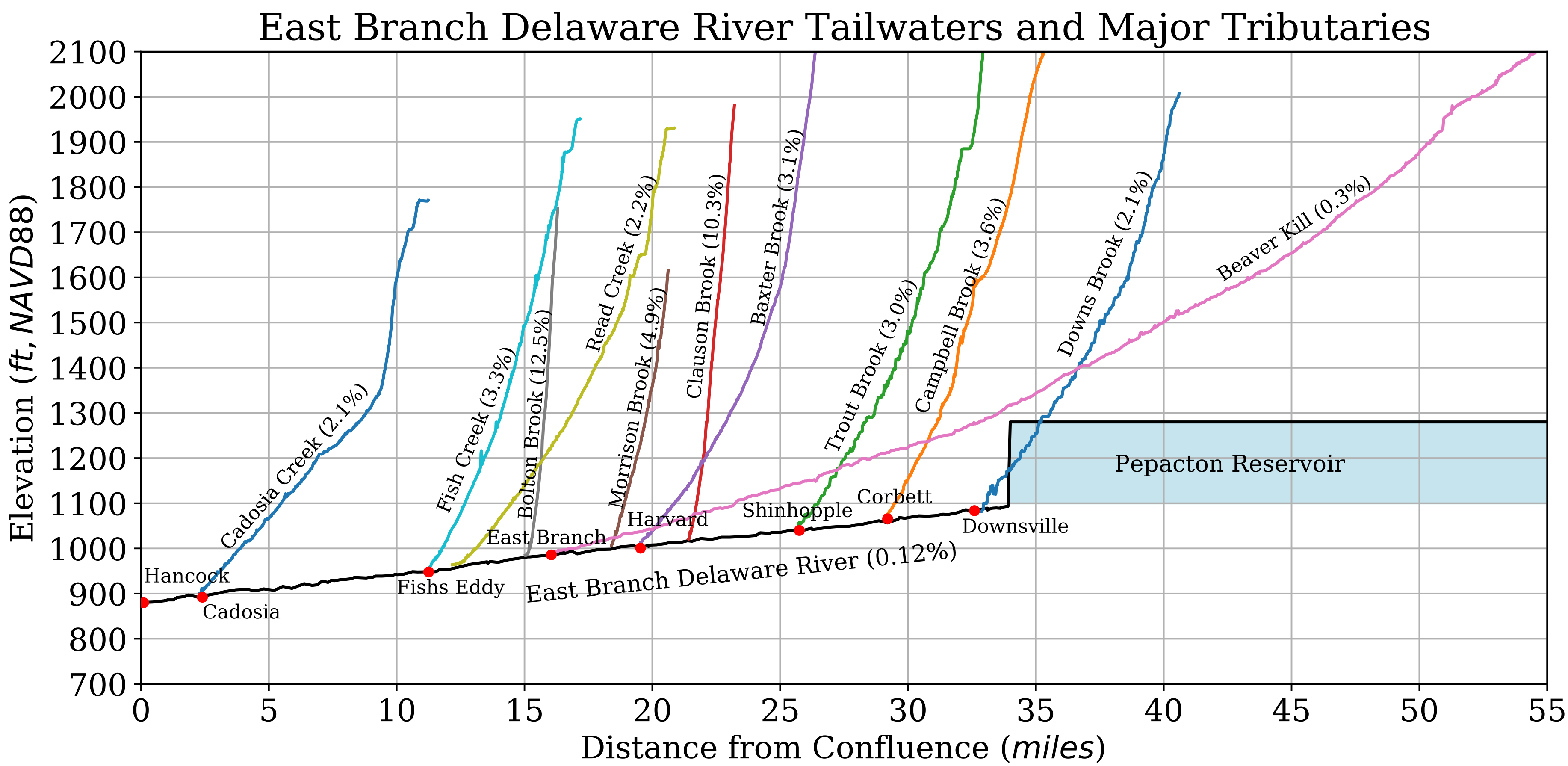

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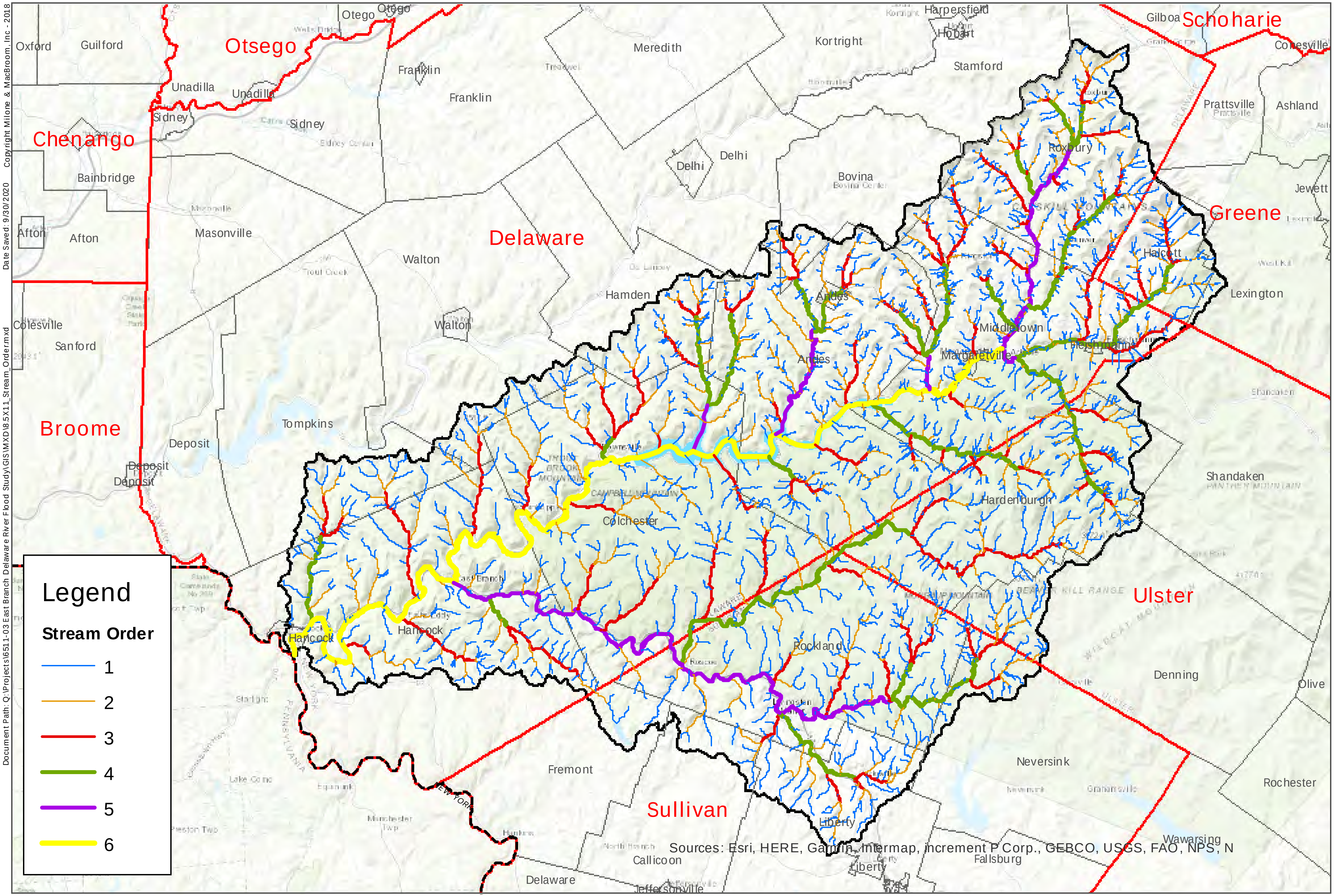

EBDR STREAM ORDER

EAST BRANCH DELAWARE RIVER FLOOD STUDY - DS060

FIGURE 2-6

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2.3 Hydrology

Hydrologic studies are conducted to understand historical, current, and potential future river flow rates, which are a critical input for hydraulic modeling software such as Hydrologic Engineering Center – *River Analysis System* (HEC-RAS). These often include statistical techniques to estimate the probability of a certain flow rate occurring within a certain period of time based on data from the past; these data are collected and maintained by the United States Geological Survey (USGS) at thousands of stream gauging stations around the country. For the streams without gauges, the USGS has developed region-specific regression equations that estimate flows based on watershed characteristics, such as drainage area and annual precipitation, as well as various techniques to account for the presence of nearby stream gauges or to improve analyses of gauges with limited records. These are based on the same watershed characteristics of gauged streams in that region so are certainly informative although not as accurate or reliable as a gauge due to the intricacies of each unique basin.

For the purposes of this study, we are primarily concerned with the more severe flood flows, although hydrologic analyses may be conducted for the purposes of estimating low flows, high flows, or anywhere in between. The commonly termed "100-Year Flood" refers to the flow rate that is predicted to have a 1 percent, or 1 in 100, chance of occurring in any year. A "25-Year Flood" has a 1 in 25 chance of occurring (4 percent) every year. It is important to note that referring to a specific discharge as an "X-Year Flood" is a common and convenient way to express a statistical probability but can be misleading because it has no bearing whatsoever on when or how often such a flow actually occurs.

The EBDR watershed is relatively well gauged, both in terms of density of stations and the long time periods over which many have been under continuous operation. However, these records represent a broad range of hydrologic conditions as the construction of the Pepacton Reservoir and the reforestation of the EBDR's watershed have dramatically influenced the hydrology of the basin over the past several decades. Some stream flow gauge records in the EBDR watershed span over a century, and considerable land use change has occurred over this time.

> Estimated flood hydrology may be affected by the availability and quality of data and observations from the past and the methodology used to extrapolate from this information.
>
> Actual flood flows can be affected by land use and soil characteristics, flow regulation, antecedent conditions, stream hydraulics, and climatic inputs like the intensity and duration of rainfall.

Most of the hillsides that were bare in the early 1900s, having been cleared for timber resources and agriculture or stripped for bluestone extraction, were substantially reforested by the close of the century. This succession has influenced the runoff response of the watershed, and a rainfall event of a given intensity and duration is likely to have produced significantly different peak discharges on the EBDR over these gauges' periods of record. The influence of changing land use patterns on flood magnitude over the years is difficult to untangle from the impacts of the Pepacton Dam, which was constructed in the early 1950s, a time period when the forestry and agricultural industries in the watershed were in decline. Both the dam and these land use changes would generally act to reduce peak flood magnitude in the EBDR tailwaters by "flattening the curve" of the flood wave, assuming fixed meteorological and climatic conditions.

According to the USGS, control of the EBDR by the Pepacton Dam began in September 1954. This date is used as a cutoff for statistical analyses of flood recurrence intervals performed on stream gauging data for the EBDR, even when the records of those stations extend farther into the past. This approach is intended to isolate the current hydrological conditions from both the climate and the landscape of the past while retaining a sufficient period of record for statistical reliability. The beginning of flow regulation represents one of the greatest single changes to the EBDR's hydrology in hundreds or possibly thousands of years, effectively and abruptly establishing the river's current hydrologic regime. A limited assessment of the Pepacton Reservoir's impact on flooding and flood attenuation in the EBDR tailwaters is presented in Section 4.1 of this report.

Along with the location, duration, and intensity of a storm, the flooding that may result from a rainfall event can vary widely depending on the unique hydrology of each basin. Characteristics of local topography, soils, vegetation cover and type, bedrock geology, land use and cover, river hydraulics and floodplain storage, ponding, wetland, and reservoir storage, combined with antecedent conditions in the watershed such as snow pack or soil saturation, can impact the timing, duration, and severity of flooding.

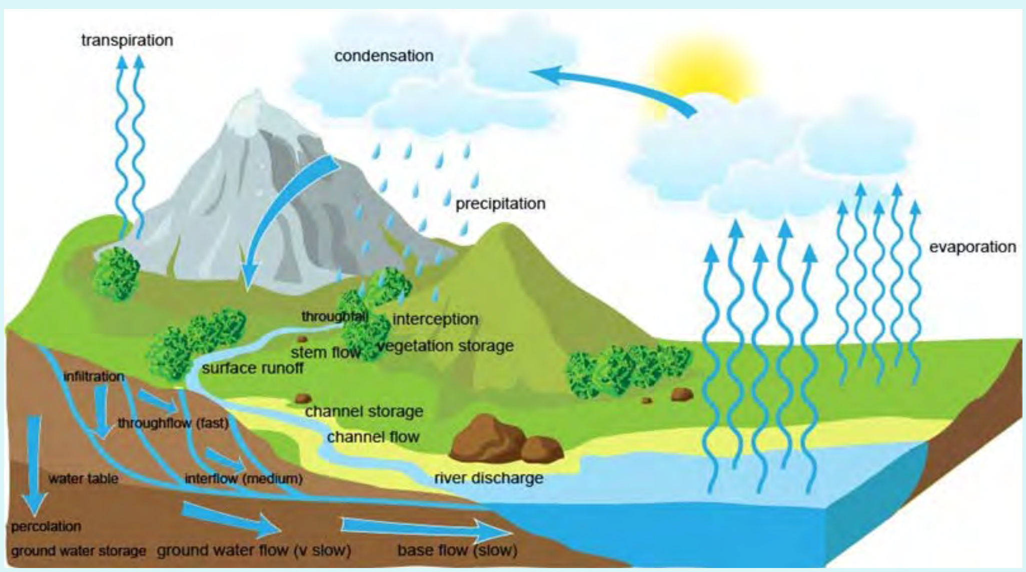


Figure 2-7: Diagram of Simplified Hydrologic Cycle

While the reservoir has undoubtedly had a substantial influence on flows and flooding on the EBDR, it is important to note that hydrologic analyses themselves can evolve rapidly over short periods of time. Statistical methods for determining flood return intervals are used to extrapolate the magnitude and frequency of flood events based on limited data sets. This enables the magnitude of the more severe floods to be estimated when often they have not been observed or recorded. The inclusion of recent extreme flood events on the EBDR has had a considerable impact on estimated peak-flood discharges. Table 2-5 shows the influence of the flood events of 2004, 2005, 2006, and 2011 on the results of USGS Bulletin 17B gauge analysis of EBDR flows since construction of the Pepacton Reservoir. These dramatic changes have occurred primarily due to four events over a short period of time, so even fairly recent hydrologic studies of the EBDR may have produced very different results than those computed based on the most current data, even when based on the same modern techniques. Such major changes in the results of hydrologic investigations may also result from advances in methodologies, growth of stream gauge record databases, or flow regulation and land use change as discussed above.

TABLE 2-5
Impact of Recent Flood Events on Estimated EBDR Flood Hydrology at Downsville Gauge

Recurrence Interval (years)	Discharge 1954-2003 (cfs)	Discharge 1954-2019 (cfs)	% Change
500	33,400	54,500	+63
200	25,300	39,900	+57
100	20,100	30,800	+53
50	15,600	23,200	+48
25	11,800	16,900	+44
10	7,500	10,300	+37
5	4,900	6,500	+31
2	2,200	2,600	+22

In the case of the EBDR, this is reflected in the substantial expansion of the SFHA between the last two Flood Insurance Studies (FIS). Table 2-6 presents the estimated peak-flood flows on the EBDR at the Downsville gauge that were used in FEMA's 1987 and 2012 hydraulic analyses. These marked differences resulted in increases in computed BFE of up to 4 feet or more in the hamlet of Downsville. On the other hand, BFE in some areas within the hamlet of Harvard were reduced by up to 3 feet in the newer FIRM. These and other increases or reductions to BFE from one FIS to the next can be due to updated hydrologic data as discussed above or can be from improvements in hydraulic modeling techniques. In other cases, changes in flood mapping may result from updated or refined topographic data, bridge replacements, or other physical changes to the river or floodplains, any of which can occur along with or independently of updates to flood hydrology. Such changes can be a source of confusion and frustration for residents who may be mapped into or out of the SFHA, as well as the local administrators who are tasked with enforcing floodplain regulations that affect the insurance premiums and property development requirements for others in the community.

TABLE 2-6
FEMA Estimated Peak Flows

Recurrence Interval (years)	1987 Flood Insurance Study	2012 Flood Insurance Study	% Change
500	13,700	35,000	+232
100	11,900	22,870	+139
50	10,800	18,400	+110
10	7,350	9,686	+67

Peak-flood flow rates along the EBDR developed for the most recent FIS were employed for one-dimensional modeling of the main stem of the river. These were developed from a drainage areaweighted regression developed specifically for this watershed based on statistical analyses of the stream gauges at Downsville, Harvard, and Fish's Eddy. These flows were used with the accompanying hydraulic model because they are the current regulatory standard and were derived from a recent and comprehensive hydrologic study.

Supplementary detailed hydrologic analyses were conducted for Downs Brook and the Beaver Kill as well as the EBDR at their confluences in Downsville and East Branch, respectively. These were employed in two-dimensional hydraulic modeling of flooding and mitigation alternatives in these two communities. At Downsville, peak flows on the EBDR were estimated based on USGS Bulletin 17B analysis of the USGS gauge at Downsville (01417000) for the years subsequent to regulation by the Pepacton Dam. Downs Brook is not gauged, so flows were estimated based on USGS Bulletin 17B analysis of the Mill Brook gauge near Dunraven (01414500), a record that covers 1937 to present. Flows from Mill Brook's 25-square-mile watershed were scaled to Downs Brook's 27-square-mile watershed using Equation (5) in USGS SIR 2006-5112. This includes the watershed area of the Wilson Hollow Brook tributary. Observed flood hydrographs of the 1996, 2004, 2005, 2006, and 2011 floods at these gauges were used for model calibration.

For hydraulic modeling at East Branch, USGS Bulletin 17B analyses were performed for the EBDR gauge at Harvard, roughly 1 mile upstream of the model's upstream extent. The same analysis was performed for the Beaver Kill, which is gauged at Cooks Falls, about 10 miles upstream of East Branch. At their confluence, although these two rivers have comparable drainage areas, flows on the EBDR are affected by the Pepacton Reservoir while the Beaver Kill is unregulated. As a result, the properties of the flood hydrographs on these two rivers in the 1996, 2004, 2005, 2006, and 2011 floods are markedly different, enabling decomposition of the flood wave at the gauge at Fish's Eddy, just downstream of this major confluence. This analysis facilitated calibration of modeled Beaver Kill flows to account for both additional watershed area and travel time between Cooks Falls and East Branch.

The web-based tool, "Application of Flood Regressions and Climate Change Scenarios to Explore Estimates of Future Peak Flows," developed by the USGS (Burns et al., 2015a,b) was used to obtain estimates for changes to peak-flood flows under a range of projected climate change scenarios at different periods in the future. This tool is currently only available for New York State and was used to assess flooding conditions that may occur in future decades, enabling proactive flood mitigation measures. These may include restricting development in areas that are not currently regulated floodplains but are reasonably expected to be in the future based on climate change projections or identifying bridges that currently perform well but may become hydraulically inadequate in the future.

Precipitation data were evaluated for two future scenarios, termed "Representative Concentration Pathways" (RCP), that provide estimates of the extent to which greenhouse gas concentrations in the atmosphere are likely to change through the 21st century. RCP refers to potential future emissions trajectories of greenhouse gases such as carbon dioxide. RCP 4.5 is considered a midrange-emissions scenario, and RCP 8.5 is a high-emissions scenario. Resulting precipitation and runoff estimates are based on five different climate models and are input into the USGS *StreamStats* program, a web-based implementation of regional hydrologic regression equations. Percent increases over *StreamStats* regression estimates based on current climatic data, as computed for the watershed just upstream of the confluence with the WBDR, were applied to corresponding design flood flows in the FEMA hydraulic model at the 29 flow change points in the EBDR model downstream of the Pepacton Reservoir. The flows based on the more moderate greenhouse gas scenario for the upcoming 25-year period (2025-2049) were used in the model. Mean estimated increases based on the five climate models are presented in Table 2-7. These are based on regressions for Flood Frequency Region 3 in New York.

TABLE 2-7
Predicted Increases in Flows on the EBDR
(based on two climate change scenarios for three periods in the future as measured just upstream of the confluence with the WBDR)

Flood Event (years)	RCP 4.5 (% Increase)			RCP 8.5 (% Increase)		
	2025-2049	2050-2074	2075-2099	2025-2049	2050-2074	2075-2099
500*	1	1	1	1	1	2
200	1	2	2	2	2	3
100*	2	3	3	2	3	4
50*	2	4	3	3	4	6
25	3	5	4	3	5	7
10*	3	6	5	4	6	9
5	4	7	6	5	7	10
2	5	9	8	6	9	14

* FEMA flow profile

Projected future flows for the 50- and 100-year flood events were modeled as these are important design flows for bridges. More significant changes are projected for more frequent flow events, which are generally more appropriate for use in smaller culvert design; replacement structures on the EBDR and its tributaries should consider the future flow scenarios that are appropriate for the required design flows and anticipated structure lifespan. Hydraulic profiles of both existing conditions and projected future flow increases at bridges in High Risk Areas along the EBDR are plotted in their respective sections. Changes in peak flood flows on the order of 2% to 4% are not sufficient to render any bridges inadequate if they were not already, and no dramatic increases in backwater flooding were observed. However, slight increases in flow magnitudes, especially if coupled with an increased frequency of occurrence, may exacerbate or initiate chronic issues. It is recommended that all future bridge replacements along the EBDR be accompanied by a new hydrologic analysis of the river's gauges and that conservative future flow increases be applied as well.

2.4 Hydraulics

In order to develop hydraulic modeling to assess flood mitigation alternatives, effective FEMA HEC-RAS hydraulic models were obtained for areas of the EBDR watershed where they were available, which is limited to the EBDR and Beaver Kill. Models were obtained from the NYSDEC, Floodplain Management Section, Bureau of Flood Protection and Dam Safety, which is gratefully acknowledged.

Hydraulic analyses on the EBDR, Downs Brook, and Beaver Kill were conducted using the HEC-RAS computer software. This program was developed by the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center and is the industry standard for riverine flood analysis.

The model is used to compute water surface profiles for one- and two-dimensional, steady- and unsteady-state flow conditions. The system can accommodate a full network of channels, a dendritic system, or a single river reach. Recent advancements in computer processing power have enabled practical application of two-dimensional hydraulic modeling in a growing range of situations. HEC-RAS is capable of modeling water surface profiles under subcritical, supercritical, and mixed-flow conditions. Water surface profiles are computed from one cross section to the next by solving the one-dimensional energy equation with an iterative procedure called the standard step method. Energy losses are evaluated by friction (Manning's Equation) and the contraction/expansion of flow through the channel. The momentum equation is used in situations where the water surface profile is rapidly varied such as hydraulic jumps, mixed-flow regime calculations, hydraulics of dams and bridges, and evaluating profiles at a river confluence. Two-dimensional modeling employs the St. Venant shallow water approximations of the Navier-Stokes equations as numerically discretized by HEC.

One-dimensional hydraulic modeling commissioned by FEMA for its 2012 FIS was obtained and employed in flooding analyses on the tailwater reach of the EBDR and Beaver Kill in East Branch. These HEC-RAS models were used to assess the influence of bridges on flooding extents and identify flood-prone areas within communities, including homes, businesses, roadways, and critical facilities. This model was also used in a limited assessment of sediment transport capacity for the EBDR at seven tributary junctions.

Changes to BFE that are predicted based on the future flows analysis described above are generally on the order of 0.1 to 0.2 feet of rise over existing. This is consistent with the relatively moderate predicted increase in discharge of 2 percent.

As part of this study, additional cross-sectional channel survey was collected in 2019 that enabled development of a two-dimensional hydraulic model for the lower reaches of Downs Brook at its confluence with the EBDR. New survey extended from the confluence with the EBDR and extending upstream along Downs Brook for approximately 1 mile.

Two-dimensional modeling of the EBDR and Beaver Kill was developed at their confluence in East Branch based on Light Detection and Ranging (Lidar)-derived topography channel bathymetry interpolated from FEMA modeling. This hamlet is protected by a levee, although the structure was originally constructed for ice jam mitigation and is not accredited by FEMA. It has been proposed to raise this levee and seek accreditation under the NFIP to reduce insurance premiums and alleviate development restrictions in this community. The intricacies of accredited levee design and construction notwithstanding, hydraulic modeling was conducted to assess the feasibility and practicality of the proposed levee enhancement. Two-dimensional unsteady modeling enabled assessment of the dynamic tailwater conditions that exist at this major confluence as well as calibration of the model to high-water marks surveyed by the USGS following the 2004 and 2006 floods.

2.5 Planning Documents

Village and Town of Hancock Tourism Plan (SUNY ESF, 2007)

While the plan is dated at this point, issues and opportunities identified in the document may still be relevant. Therefore, we have summarized the highlights related to flooding. The plan noted that many of the tourists to the region are there for opportunities to recreate on the Delaware River, particularly for fishing. Access limitations to the river were noted as a concern, and the lack of boating in particular was found to be an issue that was recommended to be addressed through a balance of improving access while at the same time protecting the river. Flooding was noted as a seasonal concern related to transportation, roads and scenic byways, and the issues it can present to accessibility and safety as well as the damage it does to roads, homes, and infrastructure. Hancock was noted as having the potential to become a hub for recreation in the area. There are several recommendations related to redevelopment and land use design that may be useful for consideration in other elements of this study, including developing a wildlife viewing platform overlooking the river, creating a river walk in the Village, improving river access, expanding river rescue abilities, and creating scenic byway pull-off areas.

Village of Hancock Economic and Community Development Plan (Planit Main Street, 2008)

The plan includes a Vision Statement that does not specifically reference flooding but does discuss providing "...sustainable public infrastructure...to meet growing community needs in a cost-effective manner." The study found that many of the vacant parcels in the Village were either within the floodplain or contained wetlands or steep slopes. Any development on infill sites was recommended to complement the design aesthetic of adjacent properties with streets being interconnected where feasible.

Town of Hancock Design Standards (2012)

The design standards adopted by the town were incorporated into the town's Site Plan Review Law. The regulations cover elements such as site design and general compatibility of proposed site development elements, vehicular circulation and access, parking and loading, stormwater and drainage, water and sewer proposals, landscaping, fire-related safety provisions, surface water impact, impact on the neighborhood, and impacts on agriculture, forestry, and mining.

Village of Hancock Zoning Code

The Village Zoning Code includes two residential districts, two business districts, an industrial district, and a Flood Hazard District (OF). The OF District is an overlay that uses the FEMA Zone A flood zone as the boundary. Its purpose is to designate areas where construction controls may be imposed because of varying degrees of flooding potential. The District requires development in this area to be consistent with the U.S. Flood Disaster Protection Act in addition to the underlying zoning district regulations. The Zoning Code includes Special Permit requirements for several uses, including group homes, retirement homes, churches and cemeteries, multifamily conversions, campgrounds, mobile home parks, drive-in facilities, hotels and motels, junkyards, motor vehicle repair shops and retail gasoline outlets, and bed-and-breakfast establishments. All districts also have yard and lot design criteria, including criteria for waterfront lots. Any waterfront lot is required to be located no less than 100 feet from the high-water line of the abutting waterbody.

HMP Jurisdictional Annex for the Village of Hancock

The Jurisdictional Annex document provides details related to hazard vulnerabilities in the Village, a history of damage events, and significant related information on hazards. The HAZUS-MH estimates in the document showed that for a 1 percent annual chance event, 289 people may be displaced and 213 may seek short-term shelter. This represents nearly 16 percent and just over 2 percent of the town's population, respectively. For the 0.2 percent annual chance event, the document estimated that 428 people (just over 19 percent) may be displaced and 94 people (just over 4 percent) may seek short-term shelter. In total, there was just over $21M of total assessed property exposed to the 1 percent annual chance event and over $22M for the 0.2 percent chance event. The Annex lists future needs to better understand risk/vulnerability. This effort would require significant fieldwork to identify details related to each property that has been identified as being vulnerable to flooding.

HMP Jurisdictional Annex for the Town of Colchester

The Jurisdictional Annex document provides details related to hazard vulnerabilities in the town, a history of damage events, and significant related information on hazards. The HAZUS-MH estimates in the document showed that for a 1 percent annual chance event, 235 people may be displaced and 115 may seek short-term shelter. This represents over 11 percent and 5 percent of the town's population, respectively. For the 0.2 percent annual chance event, the document estimated that 272 people (just over 13 percent) may be displaced and 135 people (just over 6 percent) may seek short-term shelter. In total, there was over $19M of total assessed property exposed to the 1 percent annual chance event and a slightly higher amount over $19M for the 0.2 percent chance event. The Annex lists future needs to better understand risk/vulnerability. This effort would require significant fieldwork to identify details related to each property that has been identified as being vulnerable to flooding.

Delaware County Multi-Jurisdictional Hazard Mitigation Plan

The purpose of Hazard Mitigation Plans (HMP) is to identify policies and actions that will reduce risk in order to limit losses of property and life. Flood hazard mitigation, in particular, seeks to implement long- and short-term strategies that will successfully limit loss of life, personal injury, and property damage that can occur due to flooding (URS, 2009). Flood mitigation strategies are most successful when private property owners; businesses; and local, state, and federal governments work together to identify hazards and develop strategies for mitigation (Tetra Tech, 2009).

The benefits of HMPs include but are not limited to the following:

- An increased understanding of hazards faced by communities
- A more sustainable and disaster-resistant community
- Financial savings through partnerships that support planning and mitigation efforts
- Focused use of limited resources on hazards that have the biggest impact on the community
- Reduced long-term impacts and damages to human health and structures and reduced repair cost (Tetra Tech, 2013)

Flood hazard mitigation planning is promoted by various state and federal programs. At the federal level, FEMA administers two programs that provide reduced flood insurance costs for communities meeting minimum requirements: the NFIP and the Community Rating System (CRS)

(Tetra Tech, 2013). Flood hazard planning is a necessary step in acquiring eligibility to participate in these programs (URS, 2009).

In 2013, Delaware County completed a multijurisdictional natural HMP. By participating in the plan, jurisdictions within the county comply with the Federal Disaster Mitigation Act of 2000. Compliance with this act allows jurisdictions to apply for federal aid for technical assistance and postdisaster mitigation project funding.

Hazards were ranked based on probability of occurrence and impact on the community. Delaware County was assigned an occurrence ranking of 'frequent' or '3' for flooding, indicating a hazard event that is likely to occur within 25 years. The impact ranking is determined based on the impact on population, impact on property (general buildings and critical facilities), and impact on the economy. A ranking of high, medium, or low is assigned to each of these factors based on historic losses and subjective assessment and is then used to calculate the overall ranking. Flooding in Delaware County was assigned a ranking of 'medium.' As a result, the overall hazard ranking for flooding in Delaware County is 'high.'

According to the HMP, FEMA has identified 103 National Flood Insurance Program (NFIP) policies for the Town of Colchester, with 29 policies located in the 1% annual chance flood boundary, 38 policies in the 0.2% annual chance flood boundary, and 65 policies located outside the 0.2% annual chance flood boundary. The Town of Colchester has 12 Repetitive Loss properties and two Severe Repetitive Loss properties. FEMA has identified 121 NFIP policies for the Town of Hancock, with 24 policies located in the 1% annual chance flood boundary, 31 policies in the 0.2% annual chance flood boundary, and 90 policies located outside the 0.2% annual chance flood boundary. The Town of Hancock has 12 Repetitive Loss properties and two Severe Repetitive Loss properties.

2.6 Stakeholder Meetings

An important component of the data gathering for this study took place through stakeholder engagement. Three formal stakeholder meetings were convened by video conference call. The first meeting was held on the morning of May 15, 2020, and included participation from NYSDEC, OGS, Delaware County Soil and Water Conservation District (DCSWCD), and Friends of Upper Delaware River (FUDR). The second meeting was held on the evening of June 18, 2020, with participation from members of the Upper Delaware River Tailwaters Coalition (UDRTC), to share the results of the analysis and review initial findings and recommendations. On December 17, 2020, a second meeting was held with UDRTC to share final recommendations and gather feedback. In addition to the formal video conferences, many one-on-one conversations took place with representatives from EBDR watershed municipalities, FUDR, DCSWCD, NYCDEP, and NYSDEC.

3.0 IDENTIFICATION OF FLOOD HAZARDS

3.1 Overview of Flooding Sources

Communities along the EBDR are generally situated at the river's confluence with smaller tributaries where sediment deposition has produced relatively flat, well-drained land that is amenable to development and agriculture. These areas experienced substantial growth associated with the burgeoning agriculture, bluestone quarrying, and timber and derivative product industries in the 19th and early 20th centuries. Flooding in these communities can come from these tributaries, the EBDR, or both. The extents of tributary flooding near the confluence can be highly dependent on the presence or absence of tailwater controls from the EBDR. Depending on antecedent conditions, as well as a community's distance downstream from the Pepacton Reservoir, the dam may offer effective, albeit unpredictable, flood control services.

Photo 3-1
Damaged bridge during 1942 flood in Downsville. Courtesy of Colchester Historical Society, Downsville, New York

Several communities lie atop active depositional features such as alluvial fans and outwash deltas where aggradation is constant and natural channel migration is frequent. The surficial geology of the EBDR's tributary watersheds is comprised primarily of glacial drift, including till. This material can have vastly different characteristics depending on its specific depositional setting within the glacial environment, but much of the material that comprises these heterogenous amalgamations of materials, ranging from clays to boulders, can be transported by these steep tributaries over much of their lengths. However, while the smaller sands, silts, and clays are carried on downstream, these streams lose competence to transport the larger particles – gravels, cobbles, and boulders – once they reach the relatively flat valley floor. Because these larger stones are not readily transported by the EBDR either, over time, deposited sediments accumulate into alluvial fans, which are highly dynamic environments. Flooding in adjacent developed areas can be especially damaging.

Historical straightening, dredging, and berming of the tributaries to the EBDR has fostered incision and entrenchment of these streams. Confined flood flows can produce damaging erosive forces that attack the vulnerable, overly steep banks of the incised channels, frequently damaging or destroying adjacent roadways and property, and causing bank failures that can release enormous volumes of sediment into the stream. As a result, avulsions occur as channels are filled with sediment and debris and streams find new, and damaging, flow paths. Tributary flooding frequently occurs during highly localized, flash-flooding events that hardly register on the EBDR itself. Bridge and culvert openings clog and jam with sediment, wood, debris, or ice, and property is lost as the stream shifts its banks or flanks around bridges. Considerable time, effort, and money is expended in efforts to reclaim property and re-tame the stream, only to have the same issues develop during the very next flood. This has resulted in unstable and impaired reaches along these tributary streams, with infrastructure and property at considerable risk.

The roads that parallel the EBDR are critical routes in flood emergencies as are those that follow the tributaries up their respective valleys. Many of the latter are maintained by local municipalities with limited budgets for infrastructure, but these are often the only available detours to and from small communities when the EBDR has flooded or damaged the main roads in the valley. Emergency services are limited to the larger hamlets and villages; several communities along the EBDR must rely on external assistance and are vulnerable to being cut off due to minimal redundancy in this rural region's road networks.

3.2 Flooding History

The Catskill Mountains are subject to large storm events that are often unevenly distributed across watersheds. As a result, local flash floods can occur in one basin while adjacent areas receive little or even no rainfall. In addition to localized events, larger storms can cause widespread flooding. An examination of stream flow gauge records indicates that flood events can take place any time of the year but are generally bimodally distributed, divided into those occurring in winter and spring and those occurring in summer and fall. Floods in winter and spring are associated with rain-on-snow events and spring snowmelt while those that take place in the summer and fall are typically brought on by extreme rainfall events that are frequently associated with hurricanes and tropical storms.

Photo 3-2
Flooding in Downsville, April 1895. Courtesy of Colchester Historical Society, Downsville, New York

According to the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center database, 106 flood or flash flood events have been reported in Delaware County between 1951 and 2019, resulting in 15 deaths and over $367 million in reported damages to property and crops, although actual losses are likely considerably greater due to underreporting, lost revenues, and other intangibles. Several of the major floods that have occurred during the past century are summarized in Table 3-1 below; emphasis is placed on the more recent events for which more data are available, and this is by no means an exhaustive list. Some of these floods were experienced on tributaries in the watershed or in the EBDR watershed above the Pepacton Reservoir while the tailwater section of the EBDR did not flood proportionately. This may occur either because they were flashier flood events that were attenuated by the natural hydrological processes of the watershed, or because the Pepacton Reservoir had sufficient void to absorb the flood wave that developed upstream. Major flood events on the main stem may have occurred due to more prolonged or severe precipitation (or equivalent precipitation in the case of snowmelt events), because the reservoir was already at or near capacity when floodwaters from upstream hit, or both. Coincident flooding of the tributaries and main stem is also possible.

TABLE 3-1
Selected EBDR Flood History
Approximate return intervals are compared to effective FEMA flows at the listed location.
Damage Valuations as Reported in Delaware County Multi-Jurisdictional Hazard Mitigation Plan (Tetra Tech, 2013)

Date	Discharge (cfs) and location	Notes
October 1903	Est. 34,000 at Downsville Est. 70,000 cfs at Fish's Eddy (~Q100)	"The Pumpkin Flood" 5" to 10" of rain Historic Peak at Downsville (pre-gauge) Former historic peak at Fish's Eddy (pre-gauge) until 2006 flood
September 1938	31,400 at Harvard (>Q100)	"The Great New England Hurricane" Flood of record at Harvard gauge prior to regulation by the Pepacton Reservoir
August 1955	27,400 at Fish's Eddy (<Q10)	"$1 Billion Hurricane" (1955 dollars) Back-to-back Hurricanes Connie and Diane, less than a week apart
January 1996	53,000 at Fish's Eddy (Between Q10 and Q50)	Severe snowmelt event occurred when temperatures hit about 60 degrees and 3" or more of rain fell on 5"+ of liquid equivalent in snowpack Ice jams contributed to flooding Severe tributary flash flooding
December 2000	37,100 at Fish's Eddy (~Q10)	
September 2004	20,200 at Downsville (between Q50 and Q100) 56,300 at Fish's Eddy (just under Q50)	Remnants of Hurricane Ivan Downsville very hard hit $747k expenses or losses reported in Colchester Flood of record at Downsville gauge since construction of the Pepacton Reservoir
April 2005	19,400 at Downsville (between Q50 and Q100) 65,100 at Fish's Eddy (just over Q50)	High pre-storm flows; 3" to 6" of rain, plus snowmelt Over $3.2M losses reported in Colchester $1.6M in damages reported in Hancock
June 2006	22,100 at Harvard (Q50) 77,400 cfs at Fish's Eddy (just over Q100)	Up to 12" of rainfall Over $10.1M damages reported in town of Colchester $11.1M damages reported in Hancock Flood of record at Fish's Eddy Flood of record at Harvard since construction of the Pepacton Reservoir
June 2007		Extreme tributary flash flooding Up to 10"+ of rain fell in ~3 hours Damage to Routes 207/7 Town of Colchester reported over $7.5M in damages

Date	Discharge (cfs) and location	Notes
October 2010	45,400 at Fish's Eddy (>Q10)	Remnants of Tropical Storm Nicole 3" to 9" of rain
August-Sept 2011	44,400 at Fish's Eddy (>Q10)	Back-to-back tropical storms Irene (up to 18" of rain) and Lee (2" to 9") about a week apart

Photo 3-3
Flooding in Downsville, 1942. Courtesy of Colchester Historical Society, Downsville, New York

Figure 3-1 is a hydrograph showing annual peak flows recorded at the Fish's Eddy USGS gauge (01421000). Flood recurrence information from FEMA showing the magnitude of the 10-, 50-, and 100-year flood events has been superimposed on the hydrograph. Figures 3-2 and 3-3 show similar hydrographs from the USGS gauges at the Harvard (01417500) and Downsville (01417000) gauges, respectively. There is a noticeable reduction in the magnitude of peak flows beginning in 1954 due to the attenuating effect of the Pepacton Reservoir. This influence is reduced along with downstream distance from the reservoir as unregulated tributaries join the EBDR.

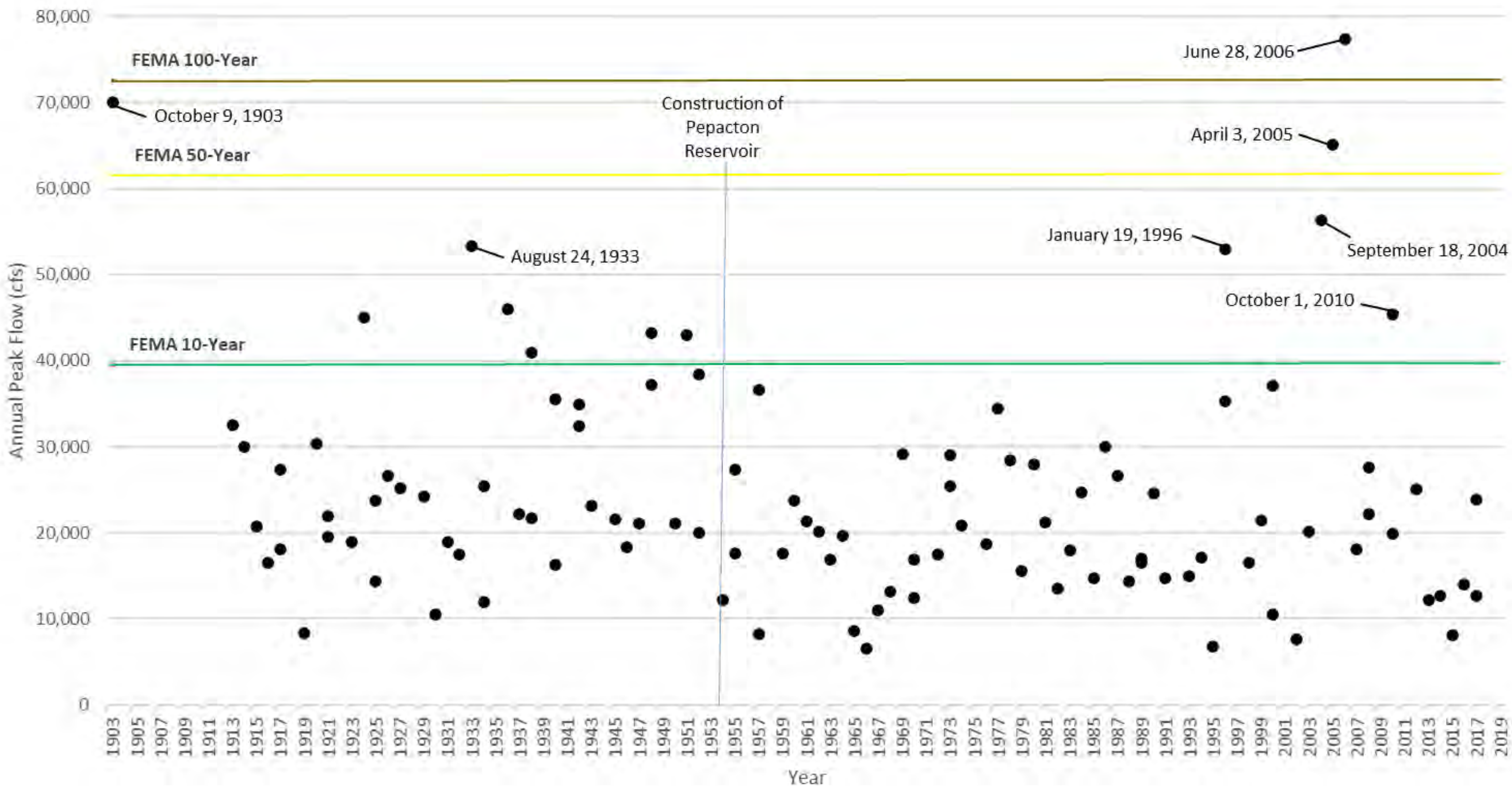


Figure 3-1:
Hydrograph of Annual Peak Flow on the EBDR at Fish's Eddy
1903 – 2019

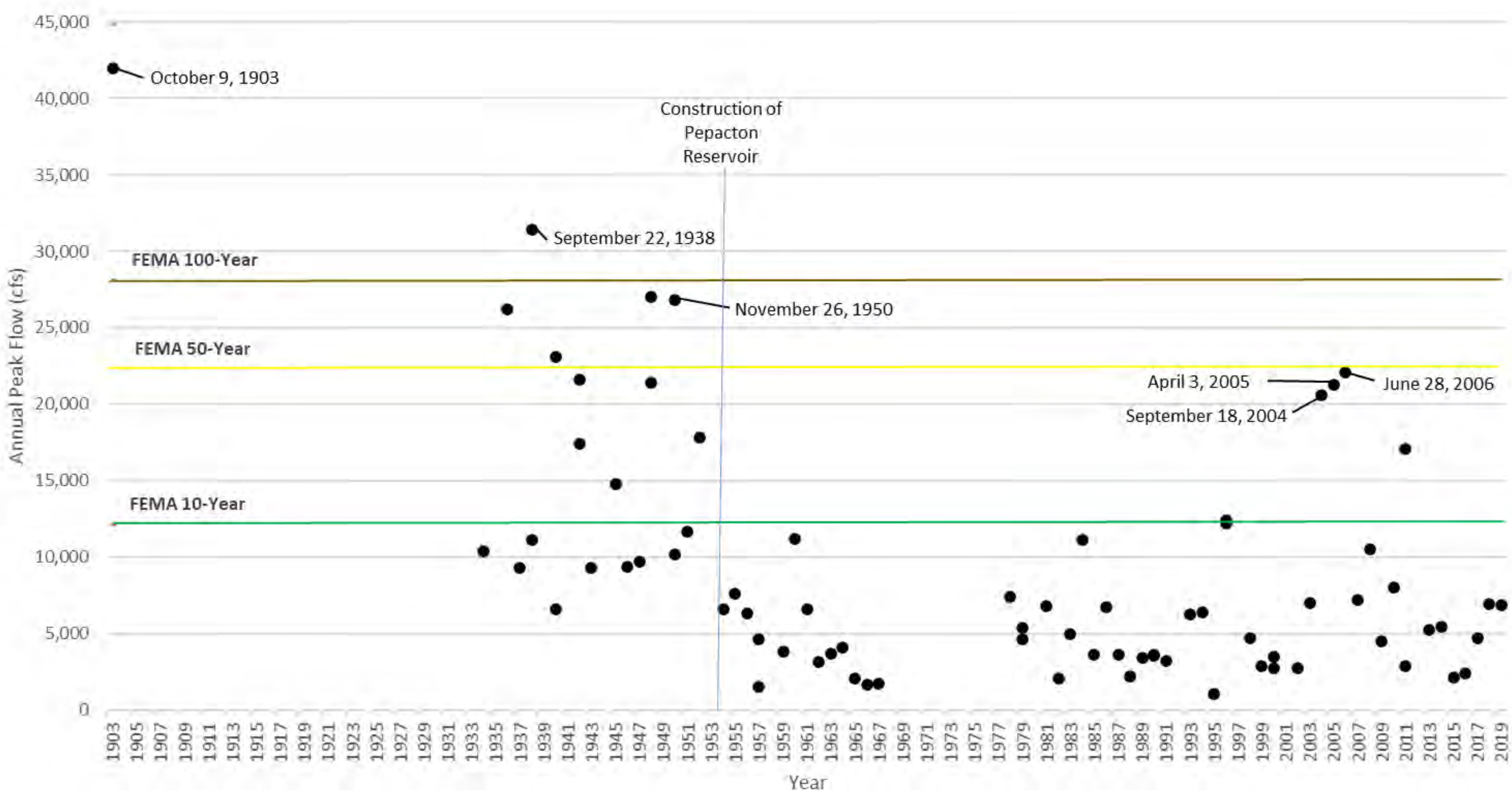


Figure 3-2:
Hydrograph of Annual Peak Flow on the EBDR at Harvard
1903 – 2019

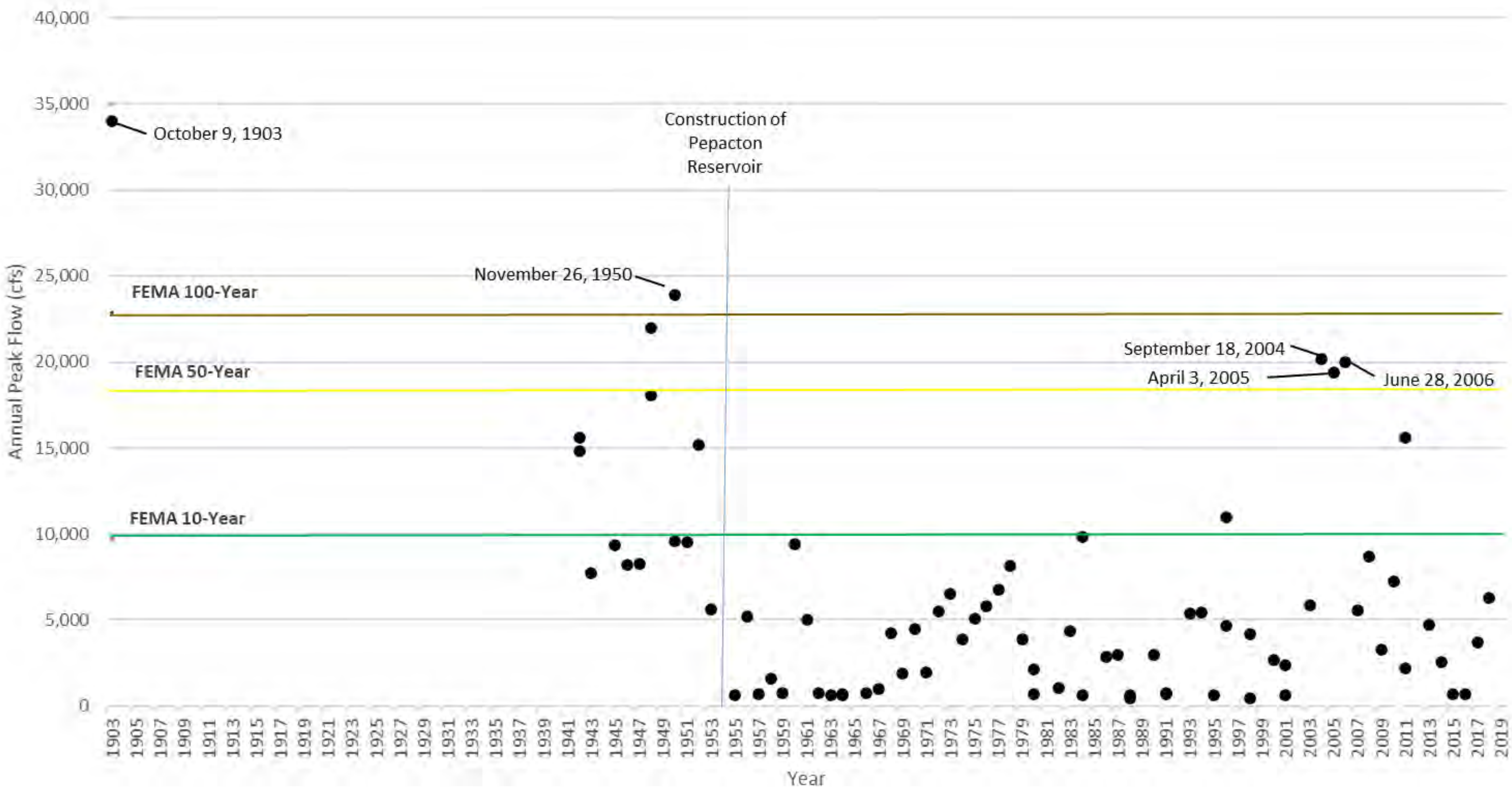


Figure 3-3:
Hydrograph of Annual Peak Flow on the EBDR at Downsville
1903 – 2019

3.3 FEMA Mapping

As part of the NFIP, FEMA produces FIRMs that demarcate the regulatory floodplain boundaries. As part of a FIS, the extents of the 100-year and 500-year floods are computed or estimated, as well as the regulatory floodway, if one is established. The area inundated during the 100-year flood event is also known as the SFHA. In addition to establishing flood insurance rates for the NFIP, the SFHA and other regulatory flood zones are used to enforce local flood damage prevention codes related to development in floodplains.

> Over the period of a standard 30-year mortgage, a property located within the SFHA will have a 26 percent chance of experiencing a 100-year flood event. Structures falling within the SFHA may be at an even greater risk of flooding because if a house is low enough it may be subject to flooding during the 25-year or 10-year flood events. During the period of a 30-year mortgage, the chance of being hit by a 25-year flood event is 71 percent, and the chance of being hit by a 10-year flood event is 96 percent, which is a near certainty.

The FIS for Delaware County (36025CV001B) has been effective since 2012, with revisions in effect as of 2016. The tailwater reach of the EBDR was not affected by these revisions; effective FIRM panels for the EBDR in the towns of Hancock and Colchester were produced based on hydraulic modeling completed in 2006, although flood extents were redelineated based on Lidar-derived topographic mapping collected in 2007.

3.4 Pepacton Dam

The NYSDEC assigns a hazard classification to dams based on the expected consequences of a dam failure. The Pepacton Dam is categorized as a Class C "high-hazard" dam. This classification indicates that "a dam failure may result in widespread or serious damage to home(s); damage to main highways, industrial or commercial buildings, railroads, and/or important utilities, including water supply, sewage treatment, fuel, power, cable or telephone infrastructure; or substantial environmental damage; such that the loss of human life or widespread substantial economic loss is likely" (NYSDEC DOW-TOGS 3.1.5). Note that this has no bearing on the dam's probability of failure but considers only the hazard that may manifest if it does.

4.0 FLOOD MITIGATION ANALYSIS

In this section, flood-prone communities along the EBDR are identified, and an analysis of flood mitigation considerations within each flood-prone community is undertaken. Factors with the potential to influence more than one EBDR community are also evaluated and discussed. These include the effect of the Pepacton Reservoir on downstream peak flows and the behavior of sediment as it is transported along the EBDR channel. These overarching factors are discussed first, followed by discussion of each flood-prone community.

High Risk Areas in communities along the EBDR were assessed for flooding hazards and potential mitigation strategies. Flood-prone areas, critical facilities, bridge constrictions, historical damages, and emergency access and detour availability were considered in these analyses. Figure 4-1 presents an overview of flood-prone communities that were evaluated.

Specific flood mitigation alternatives are detailed for individual areas are outlined where applicable. Unfortunately, the lack of modern hydrologic analyses and hydraulic modeling on tributary streams precludes in-depth alternatives analysis for high-risk areas prone to flooding from these sources. Several alternatives for these areas are presented in the Delaware County Multi-Jurisdictional Hazard Mitigation Plan. While these strategies seem appropriate, Milone & MacBroom, Inc. (MMI) did not perform additional analyses, which would require development of detailed hydraulic modeling. General recommendations are presented in Section 5. These include infrastructure improvements like bridge and culvert replacements, road relocations, stream restoration and floodplain reconnection, establishment of riparian buffers, individual property protection measures, and relocations of homes and businesses. Where hydraulic modeling of tributary stream is antiquated, it is recommended that communities in high-risk areas seek updated analyses to inform development of holistic flood mitigation strategies.

Following the identification map and matrix of each High Risk Area is a high-level conceptual relocation "Master Plan" of potential relocation areas. This is simply an exercise in identifying potential areas where relocation generally seems to make sense for residential, retail/commercial, industrial, and other land uses identified as flooded through this assessment. It in no way suggests these are the only locations or that they are adequate to relocate all properties identified as being within the floodplain. There are many caveats to the exercise, and any relocation efforts will require significant coordination between landowners eligible for relocation, landowners interested in selling land for new development, local government input, and requirements and regulations by funding and assistance agencies from the state to federal levels.

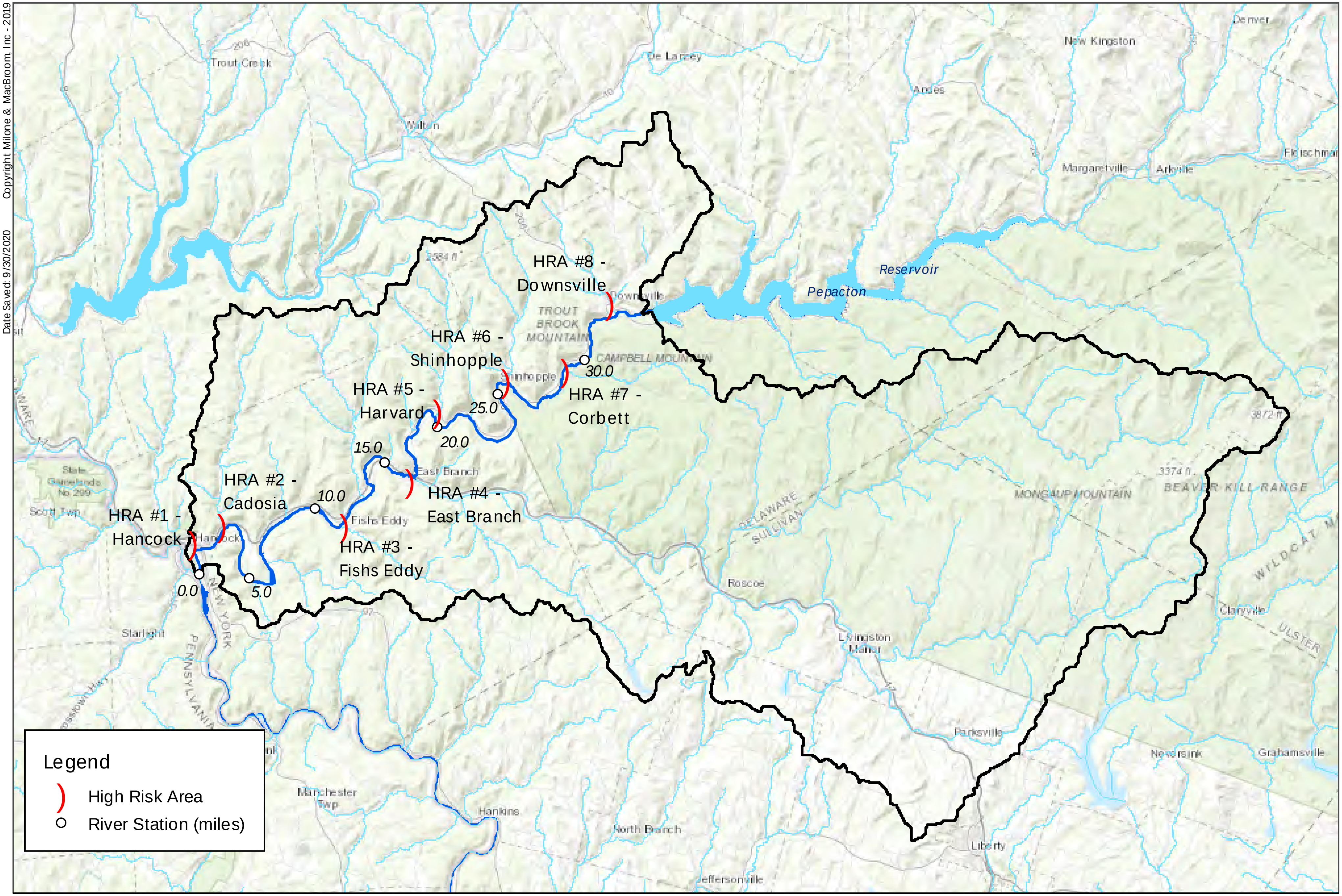
4.1 Pepacton Reservoir Influence on Flood Flows

Flooding on the EBDR may or may not coincide with void space in the Pepacton Reservoir; for a given event, the flood peak attenuation provided by the dam is neither predictable nor reliable. However, long-term trends in peak-flow statistics may be indicative of the degree to which the reservoir has impacted the flood hydrology of the EBDR. USGS Bulletin 17B analyses were performed on the annual peak-flow data recorded at the Downsville USGS gauge on the EBDR (01417000) for the years prior (1903 to 1954) and subsequent (1954 to 2019) to the construction of the Pepacton Dam. Flood recurrence intervals based on these two data sets are presented in Table 4-1.

TABLE 4-1
Peak Flows at Downsville USGS Gauge Before and After Construction of Pepacton Reservoir

Flood Event (years)	Peak Discharge (cfs)		Change (percent)
	Pre-Dam (1903 to 1954)	Post-Dam (1954 to 2019)	
500	69,300	54,500	-21
200	56,400	39,900	-29
100	47,800	30,800	-36
50	40,100	23,200	-42
25	33,100	16,900	-49
10	25,000	10,300	-59
5	19,400	6,500	-67
2	12,300	2,600	-79

Despite the fact that the Pepacton Dam creates a water supply reservoir, it is capable of providing significant flood control functions, although it is critical to be clear that the degree to which a flood's peak discharge will be attenuated is highly dependent on reservoir stage at the inception of the flood, as well as the magnitude and duration of the event. The outlet configuration of this dam limits releases to 740 cubic feet per second (cfs) (with no spilling); at this rate, even with the best forecasting, the reservoir cannot be drawn down meaningfully in anticipation of a flood event. However, managing the void is currently possible at seasonal timescales such as accounting for snowpack over the duration of a winter.



EBDR FLOOD PRONE COMMUNITIES

EAST BRANCH DELAWARE RIVER FLOOD STUDY - DS060

FIGURE 4-1

0 1.5 3 4.5 6
Miles
1 in = 4.5 miles

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The intricacies of individual events notwithstanding, analysis of peak flows before and after construction of the dam reveals what might be considered the "average" reductions in flood magnitudes that have resulted. Note that no attempt has been made to reconcile these data with length or quality of the gauge record, changes in land use, variable climatic conditions, or other complicating factors that undoubtedly exist.

Analysis of the gauge record at Fish's Eddy shows that downstream of confluence of the EBDR and Beaver Kill, the influence of the Pepacton Reservoir on flood hydrology has diminished considerably, land use and climate notwithstanding. Flood recurrence intervals are presented in Table 4-2. This is not unexpected; measured at this location, the majority of the EBDR's watershed area is unregulated. While the dam continues to affect flows, contributions from groundwater and tributaries – particularly the Beaver Kill, which drains 300 square miles – have overcome the moderating influence of the dam. Fish's Eddy is also the first gauged location downstream of the Pepacton Reservoir where mean daily flows on the EBDR consistently exceed those measured upstream of the dam at the Margaretville gauge.

TABLE 4-2
Peak Flows at Fish's Eddy USGS Gauge Before and After Construction of Pepacton Reservoir

Flood Event (years)	Peak Discharge (cfs)		Change (percent)
	Pre-Dam (1903 to 1954)	Post-Dam (1954 to 2019)	
500	87,800	101,800	+16
200	76,900	84,000	+9
100	68,900	71,900	+4
50	61,100	60,800	<1
25	53,400	50,700	-5
10	43,400	38,600	-11
5	35,700	30,200	-15
2	24,500	19,200	-22

The graphics presented in Figures 4-2 and 4-3 were creating using data from USGS gauging stations and postflood analyses (USGS Scientific Investigations Report 2014–5058, Floods of 2011 in New York, and USGS Open-File Report 2009–1063, Flood of June 26–29, 2006, Mohawk, Delaware, and Susquehanna River Basins, New York). They include hydrographs from USGS gauges located upstream (at Margaretville) and downstream (at Downsville) of the Pepacton Reservoir and demonstrate the dampening of peak flows due to the attenuating effect of the reservoir. Note that these gauged flood hydrographs are only part of the total; in its analysis, the USGS also accounted for the contributions of the several tributaries that meet the EBDR upstream of the dam but downstream of the Margaretville gauge, including those that empty directly into the reservoir. Figure 4-2 is from late August and early September 2011 when Tropical Storms Irene and Lee passed through the region. At the onset of high flows resulting from Tropical Storm Irene, the Pepacton Reservoir was filled to 94.8 percent of its capacity, meaning that the spillway of the dam at the reservoir outlet was not spilling, and there was substantial void space in the reservoir. This available void resulted in a 64 percent attenuation of peak flows. When Tropical Storm Lee arrived in the region 10 days later, the Pepacton Reservoir was full, and as a result, the attenuating effect of the reservoir on EBDR flows was not as great as it had been during Tropical Storm Irene.

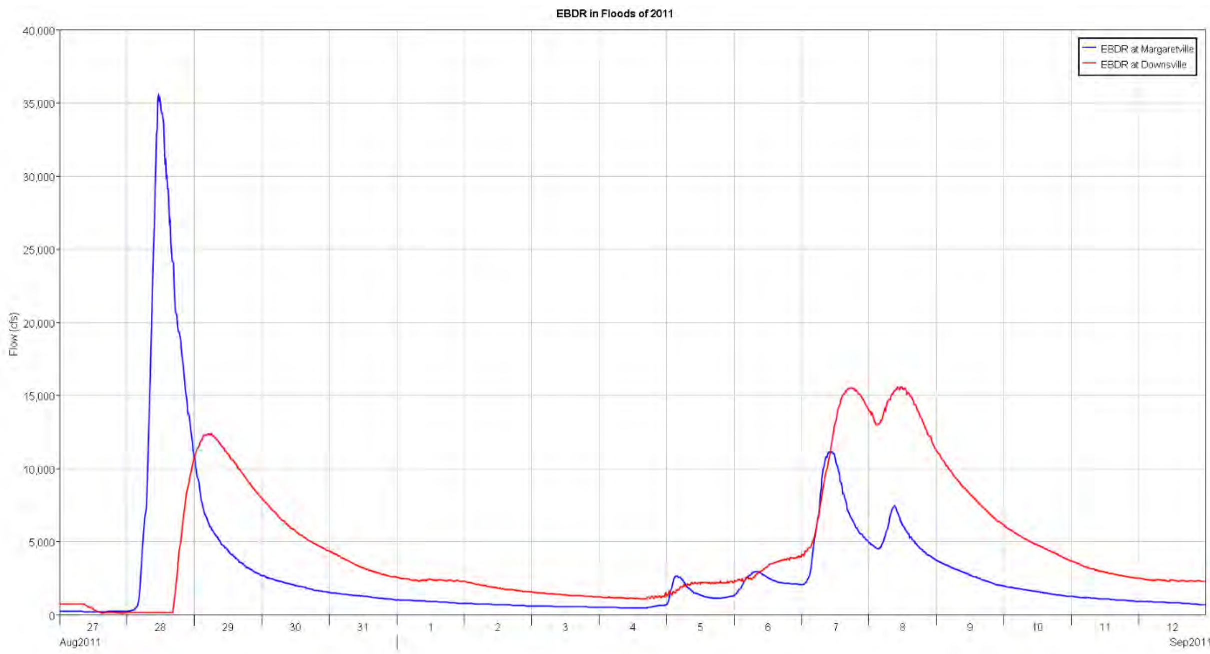


Figure 4-2:
Flow Hydrographs for the EBDR at Margaretville and Downsville during Tropical Storms Irene and Lee, 2011

At the onset of the June 2006 flood, the Pepacton Reservoir was filled to capacity and spilling, with no void (Figure 4-3). In contrast to the 64 percent attenuation seen during Tropical Storm Irene, the reservoir resulted in a 23 percent attenuation of peak flows during the 2006 flood.

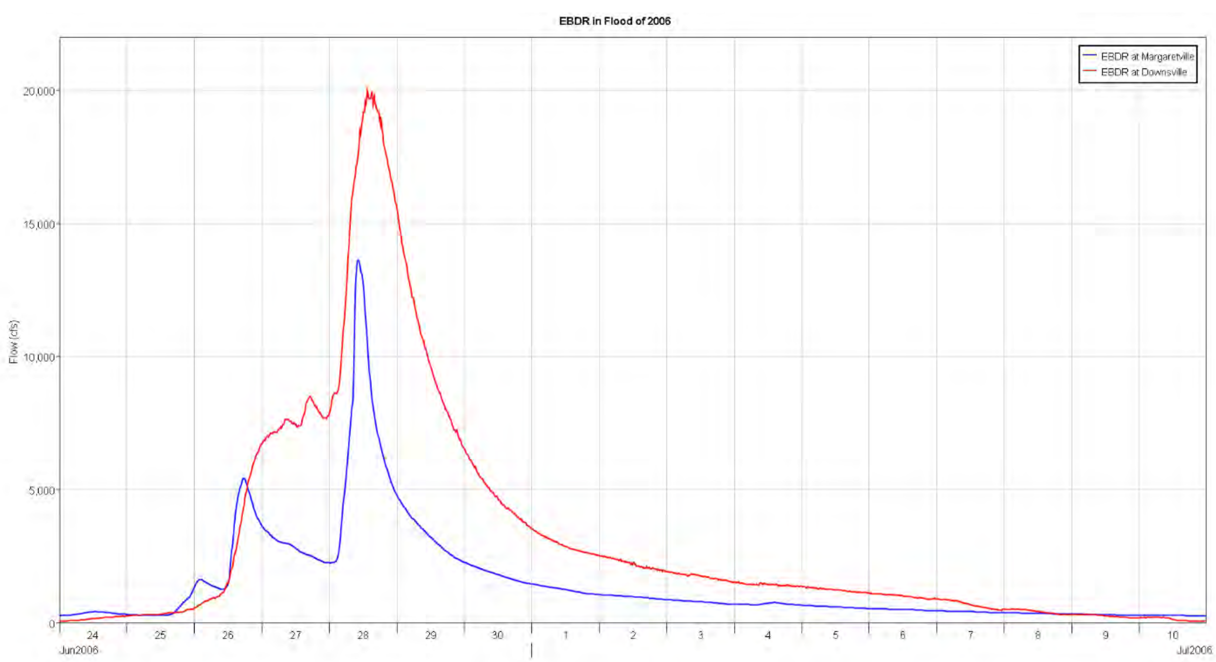


Figure 4-3:
Flow Hydrographs for the EBDR at Margaretville and Downsville during the 2006 Flood

The Pepacton Dam often operates with void volume (although it was neither designed for nor operated as a flood control structure) and can completely absorb the flood waves of smaller magnitude, more frequently occurring flood events. During more severe floods, peak flows downstream can also be significantly attenuated, even when the dam is spilling. Based on the above analysis, the following can be stated about the influence of the Pepacton Reservoir on downstream EBDR flood flows:

- The Pepacton Reservoir substantially attenuates downstream peak flows on the EBDR when it has a void at the start of a flood event.

- The Pepacton Reservoir moderately attenuates downstream peak flows on the EBDR when it has no void at the start of a flood event.

- The Pepacton Reservoir does not cause an increase in downstream peak flows during a flood event.

- The attenuating influence of the Pepacton Reservoir decreases moving downstream as tributaries contribute unregulated flow to the EBDR.

Releases and diversions from the Pepacton Reservoir are conducted in accordance with the Flexible Flow Management Program (FFMP, commonly known as the "Decree"). This agreement between the member entities of the Delaware River Basin Commission (DRBC; Delaware, New Jersey, New York City, New York State, and Pennsylvania) establishes standards and guidelines for withdrawals and minimum flows on the Delaware River, among many other responsibilities. Over 13 million people rely on the Delaware River as a water supply, the majority of whom do not live in New York. Releases from the Pepacton, Cannonsville, and Neversink Reservoirs are prescribed by the Delaware River Master (DRM) to meet combined flow targets set at the confluence of the Delaware and Neversink Rivers in Montague, New Jersey, while total diversions from the Delaware River basin for New York City cannot exceed 800 million gallons/day (1,240 cfs).

The Pepacton Reservoir can release up to 740 cfs when it is not spilling and does so at the direction of the DRM in order to fulfill various objectives in the basin related to drought management, flood mitigation, minimum flow requirements, void management, thermal management for fisheries resources, endangered species protection, and other ecological considerations in addition to maintaining a quality water supply for all users. The Pepacton Reservoir is operated to achieve goals locally, at the farthest reaches of the watershed, and even outside of it. Releases are managed to meet the needs of dozens of stakeholders, from spill reduction protocols that reduce flooding on the EBDR, to management of the location of the salt front on the Delaware River near Wilmington, Delaware. Void management in the Pepacton Reservoir is conditional upon these and other dynamics on the river.

As its name implies, the FFMP is "Flexible," and operating procedures are continuously updated based on conditions in the watershed, which may include anticipated municipal demands, measured or predicted winter snowpack, and even ecological considerations. Modifications to operations may also occur as part of scientific research projects that are developed to optimize management of the Delaware River's considerable resources for the benefit of all stakeholders. The River Master, a member of the USGS, assesses and reports on the operations along the river in general and as pertains to compliance with the FFMP for each water year. A several-year lag time on this reporting should be expected, although these thorough assessments explain and justify the various actions taken by the DRBC and member parties throughout the year. Currently, these can be accessed online at: https://webapps.usgs.gov/odrm/publications/publications

A consequence of the Pepacton Reservoir's release management is that the reliable supply of cold water supports a world-class trout fishery in the tailwaters. Fishing and recreational tourism are now a cornerstone of the economy in the EBDR tailwater valley, and various advocacy groups have undertaken considerable efforts to promote river restoration and flood recovery practices that benefit the fishery. Unfortunately, this may lead to the perception that the trout are given more consideration than local residents following flood events, which recently have been frequent and devastating. Generally speaking, many of the stream channel characteristics and features that promote quality trout habitat are shared with holistic flood mitigation and bank stabilization strategies; when properly implemented, these can be more effective and require less maintenance than traditional flood control measures such as dredging and berming.

4.2 Sediment Transport

In addition to moving water, rivers also transport sediment. During a flood event, the large volumes of water moving downstream have the potential to transport large volumes of sediment, ranging in size from fine silt and sand to large boulders. This section looks at the influence of the Pepacton Reservoir on sediment transport and at the ability of the EBDR channel to transport the course sediment that is delivered by its steep tributaries.

Photo 4-1
Sediment Bar along the EBDR

Sediment flux continuity can be disrupted by the presence of a dam. Tailwater streams often experience degradation of their channels due to a lack of inflowing sediment, which gets impounded in the upstream reservoir. Downstream of dams, deviation from dynamic equilibrium occurs as materials erode from the bed but are not replaced from upstream. This generally leads to a loss of fine sediments and armoring of the channel bed with well-imbricated coarse materials. It also frequently causes channel incision, bank failures, and long-term scour issues at bridges and other structures. Erosion during flood events can become more severe as the stream's reduced sediment load leaves it with excess energy available to expend, a phenomenon often referred to as "hungry water."

Channel degradation may also have deleterious consequences for aquatic organisms, which can be sensitive to channel sediment gradations for habitat and spawning success. The influx of sediment from the unregulated tributaries to the EBDR counteracts this process to some degree as this material replaces some of what is impounded by the Pepacton Dam. However, the presence of the dam also affects the frequency, magnitude, and timing of flood events downstream, which may impact the ability of the river to transport what is delivered by its tributaries.

The USGS conducted a bathymetric survey of the Pepacton Reservoir in 2015 and compared this with the as-built capacity of the impoundment (SIR 2017-5064). Results indicate that approximately 5.5 million cubic yards of sediment have accumulated behind the dam since its operation began in 1954, or about 0.7 percent of the total original capacity. Sediment is not delivered at a steady rate, but this translates to an average of nearly 250 cubic yards of sediment being transported by the EBDR into the Pepacton Reservoir every day (about 16 dump trucks).

Wolman pebble counts were performed on the gravel and cobble bars that have aggraded at the confluence of the following tributaries with the EBDR: Downs Brook, Campbell Brook, Trout Brook, Baxter Brook, Beaver Kill, Fish Creek, and Cadosia Creek. These steep, high-energy tributaries deposit large volumes of coarse-grained sediments when they reach the relatively flat valley bottom at their respective confluences with the main stem of the river. The sediment gradations determined from these pebble counts were used to assess the mobility of this material under flood conditions on the EBDR. The Beaver Kill is somewhat shallower than the other tributaries; this characteristic is reflected in the finer gradation of the material that it transports and deposits where it meets the EBDR.

The EBDR valley was formed by glaciers over thousands of years, but riverine processes now dominate. The system has not yet reached a new equilibrium.

The majority of the sediments transported to the EBDR are derived from deposits of glacial drift that are ubiquitous throughout the regional surficial geology. Tributaries flow through till, kame, and glacial outwash that was transported and deposited by the powerful glacial processes that shaped the EBDR valley during the Pleistocene and early Holocene. The steep tributaries in confined valleys are able to transport a large portion of this readily available substrate due to both the concentration of the stream's turbulent energy to a narrow channel and the relatively large component of gravity that acts on material in these steep channels. Channel incision and bank failures may contribute to sediment load in these tributaries as well. Regardless of its source, once this material reaches the broad, shallow-slope valley of the EBDR, shear forces and stream power are reduced, and, while finer particles like silts, sands, and smaller gravels remain mobile, the river is not competent to transport the larger gravel and cobble material at the rate it is delivered.

Naturally, this material would fall out soon upon reaching the valley floor and contribute to growth of the alluvial fan. However, channelization of tributary streams maintains some degree of energy concentration, and these coarse sediments are transported farther and end up deposited in population centers or once meeting the EBDR.

The occurrence of this phenomenon is evidenced by the gravel and cobble bars, alluvial fans, and other aggradational features that are ubiquitous at tributary junctions. In turn, these depositional features trigger morphological response by the EBDR, generally through lateral migration. As the tributaries deposit material at their confluence with the EBDR that it cannot transport, the river is forced to erode into the opposite bank. In the EBDR valley, this natural process may threaten roadways, homes, or other infrastructure or property. Along much of the river, tributary depositional features have pushed the EBDR to one or the other valley wall, which may be defined by natural terrain, or by the hard-armored embankments of Route 17 or Route 30, and further lateral migration is restricted.

In some cases, the sediment delivered to the EBDR by its tributaries can be intermittently mobilized by natural, cyclical fluvial processes. Depositional material that fills the EBDR channel behaves as a dynamic grade control, creating a locally reduced stream slope upstream of a tributary junction and an increased slope downstream. Once a threshold gradient is achieved downstream of the inflection, the aggraded sediment can mobilize, and a headcut will propagate upstream through the affected reach to reestablish an equilibrium slope. This process is unpredictable and may occur rapidly during a flood or can happen more slowly as a chronic process.

> Much of the EBDR's substrate is nonalluvial in origin, having been delivered to the valley by glacial processes several thousand years ago. Today, these sediments continue to be delivered to the valley floor by tributaries with more unit energy than the EBDR can achieve in the wide, shallow valley it has inherited.

While it was neither designed for nor operated as a flood control structure, the Pepacton Dam often has void volume and can completely absorb the flood waves of smaller magnitude, more frequently occurring flood events; during more severe floods, peak flows downstream can also be significantly attenuated even when the dam is spilling. Disruption of the natural flow regime undoubtedly has an impact on sediment flux in the EBDR downstream of the reservoir as the frequency and duration of high-flow events are reduced. However, the occurrence of floods on the EBDR with sufficient energy to transport the gravel and cobble delivered by the tributaries has not been appreciably affected. This is primarily due to the prodigious discharges required to mobilize these coarse sediments given the broad, shallow river valley geometry of the EBDR.

The competence of the EBDR to transport the sediments derived from its tributaries was quantitatively assessed using the Sediment Transport Capacity (STC) hydraulic design module of the USACE's HEC-RAS software. One-dimensional hydraulic modeling developed by FEMA was used to determine the flow characteristics necessary to assess competence, such as depth, velocity, slope, shear stress, and stream power, over a range of flood flows. Material representing both the median grain size (d50) and 84th percentile grain size (d84) of the sampled bars were assessed; the d50 is generally considered to be the characteristic particle size of the sample, and the d84 is more representative of the material that comprises the armoring layer that develops in gravel and cobble streambeds, which can effectively shield smaller particles from fluvial entrainment.

Results indicate that at the aggradational features at the assessed tributary junctions, the EBDR cannot mobilize significant quantities of representative depositional material until flows are in excess of the 50-year flood magnitude. It is critical to note that the available hydraulic modeling limits this analysis to average channel hydraulics at the reach scale; local variability in cross-sectional geometry and channel slope are not captured by this model, nor is the nonuniform lateral distribution of shear forces within the channel. Within these reaches, there are locations where flow conditions are capable of mobilizing this coarse material in lesser-magnitude flows, although generally only for relatively short distances. Results of the sediment analysis are summarized in Table 4-3 and are shown graphically in Figure 4-4.

TABLE 4-3
Sediment Size Measurements at EBDR Tributary Confluences

Tributary Junction	Mean Slope (percent)	D50 (mm)	Grain Size	D84 (mm)	Grain Size
Downs Brook	2.1	81	Small Cobble	133	Large Cobble
Campbell Brook	3.6	72	Small Cobble	115	Medium Cobble
Trout Brook	3.0	69	Small Cobble	140	Large Cobble
Baxter Brook	3.1	67	Small Cobble	121	Medium Cobble
Beaver Kill	0.3	49	Very Coarse Gravel	76	Small Cobble
Fish Creek	3.3	70	Small Cobble	120	Medium Cobble
Cadosia Creek	2.1	62	Small Cobble	124	Medium Cobble

Overall, the coarse material within the aggradational features in the EBDR is relatively stable on decadal timescales, which is the case both upstream and downstream of the Pepacton Reservoir. Fundamentally, this is because the river's substrate is nonalluvial in origin, having been delivered to the valley by glacial processes several thousand years ago. Today, these sediments continue to be delivered to the valley floor by tributaries with more unit energy than the EBDR can achieve in the wide, shallow valley it has inherited. Analysis of historical aerial imagery and mapping reveals that the river's anabranched planform and many of the depositional features within the channel have been relatively unchanged over the past 70 to 80 years. The growth of new depositional features unrelated to tributary inputs is generally limited to the slack waters downstream of bridge piers.

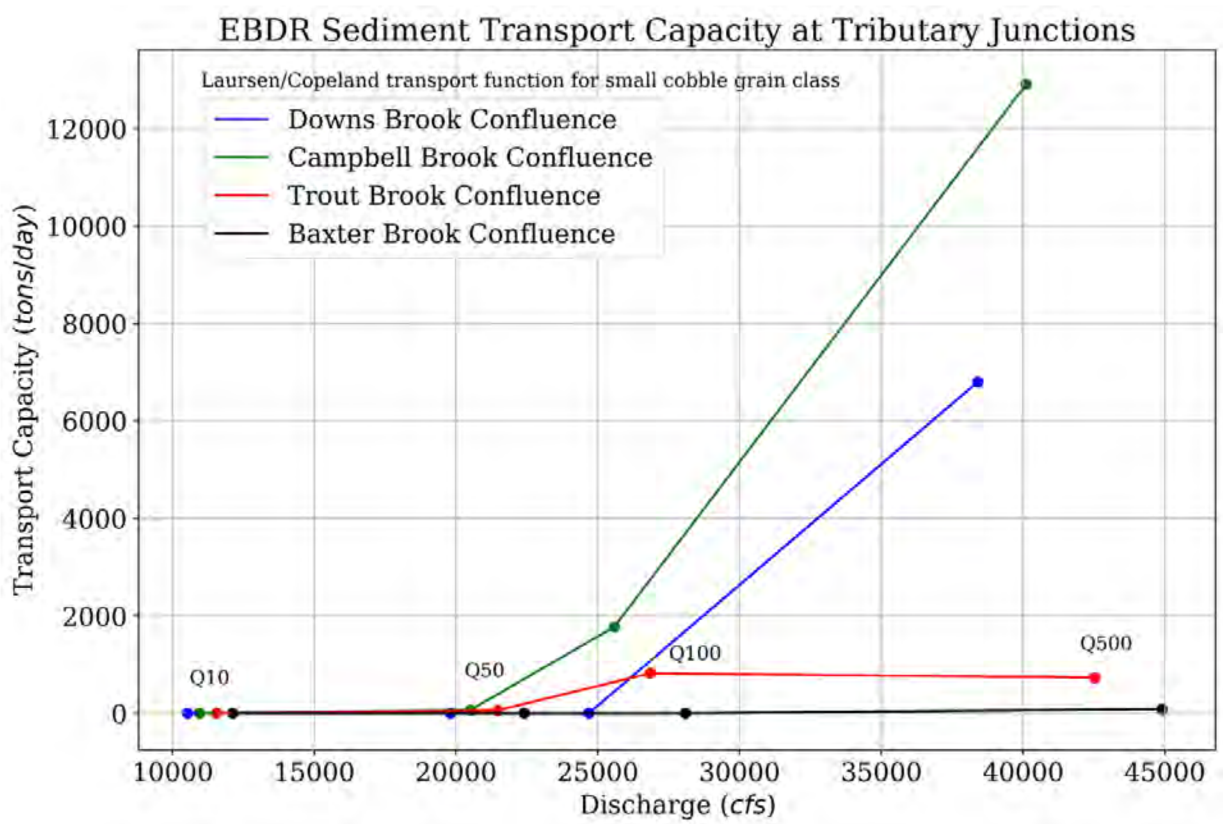


Figure 4-4: Transport capacity of small cobble grain class for the EBDR at representative tributary junctions based on FEMA modeling. Channel and valley characteristics result in some variability in competence in the most severe floods; however, at the reach scale, these coarse particles are essentially immobile in up to the 50-year flood.

Based on the above analysis, the following can be stated about sediment on the EBDR:

- The EBDR channel lacks the competence to mobilize significant quantities of depositional material until flows are well in excess of the 50-year flood (competence-limited).
- Coarse material within the aggradational features is relatively stable on decadal timescales.
- The river's substrate is nonalluvial in origin, having been delivered to the valley by glacial processes several thousand years ago.
- Today, these sediments continue to be delivered to the valley floor by tributaries with more unit energy than the EBDR can achieve in the wide, shallow valley it has inherited.
- Analysis of historical aerial imagery and mapping reveals that the river's anabranched planform and many of the depositional features within the channel have been relatively unchanged over the past 70 to 80 years.
- This is the case both upstream and downstream of the reservoirs.

4.3 High Risk Area #1 – Hancock

The village of Hancock is located at the confluence of the EBDR and the WBDR where the two branches meet to form the Delaware River proper. The village, located within the town of Hancock, is one of the larger communities along the East Branch (and West Branch) of the Delaware River. The EBDR's watershed area at its confluence with the West Branch totals 840 square miles. Hancock grew as a major crossroads and hub of commerce and industry in the Upper Delaware River basin. Assessment of the flooding hazard in the village from the WBDR and Sands Creek is detailed in the Flood Mitigation Report for the West Branch of the Delaware River.

Figure 4-6 is an aerial image of the village of Hancock showing flood-prone areas, including roads and critical facilities.

Land within the village has a significant mix of uses, many of which are located along Front Street (Route 268). The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Residential (200), Vacant Land (300), Commercial (400), Recreation and Entertainment (500), Community Services (600), Industrial (700), Public Services (800), and Wild, Forested, Conservation and Public Parks (900).

These include the following:

- Residences
- Religious institutions
- Railroad Line (New York Susquehanna & Western Railway Corp. and Norfolk Southern)
- A U.S. Post Office
- Hancock Central School property
- A NYSDOT Office
- Retail (several restaurants and a grocery store, gas stations)
- Industrial uses
- Lodging
- A golf course, the Hancock Fireman's Field, the American Legion
- A Library, the Hancock Fire Department, Town Hall, a reservoir and water tower

Two bridges span the EBDR in Hancock. The Route 97 bridge, at STA 1.2, (BIN 1035490) was constructed in 2005 and is owned by the NYSDOT. The NYSW Railway Corporation owns a crossing just downstream at STA 1.1. FEMA modeling indicates that neither the Route 97 bridge nor the NYSW railroad bridge contributes to backwater flooding up to the 100-year flood. Both structures are significant hydraulic constrictions in the modeled 500-year flood. La Barre Street and Route 97/Stockport Road are expected to be inundated in the 100-year flood. East of the village, several sections of Peas Eddy Road are also modeled as overtopping in this event. This may leave residents stranded.

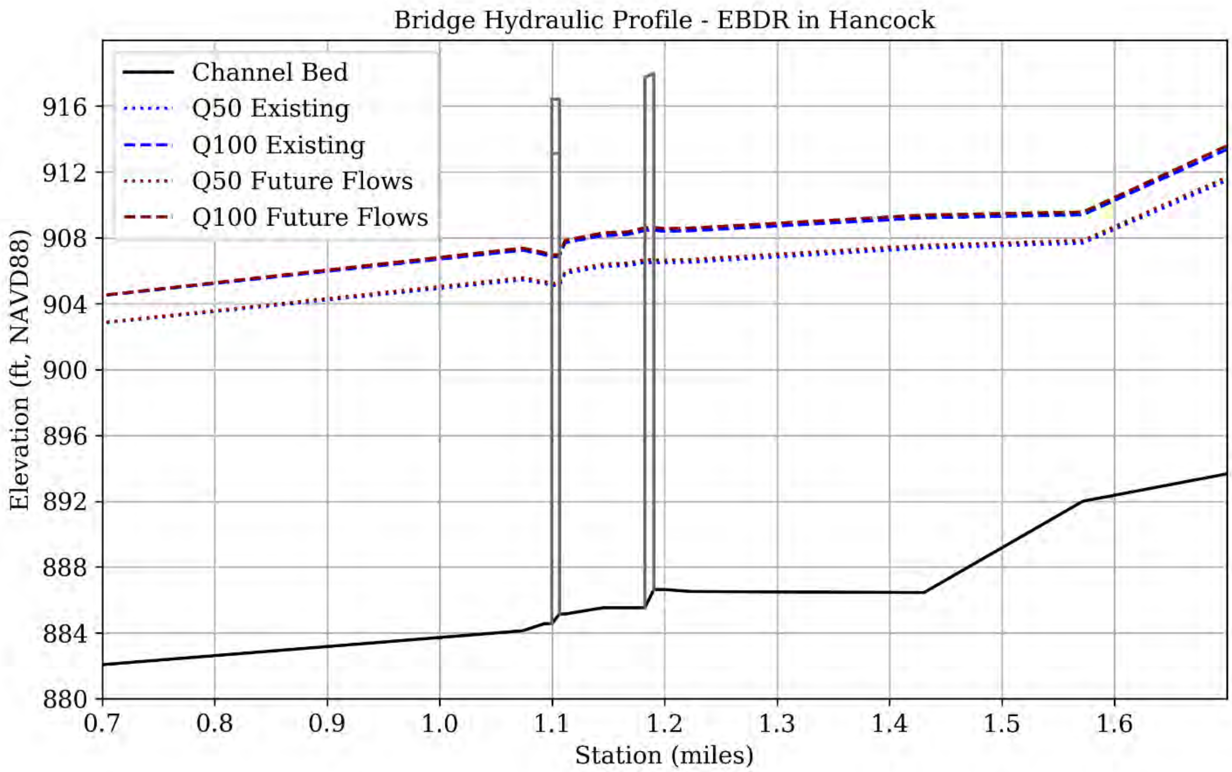


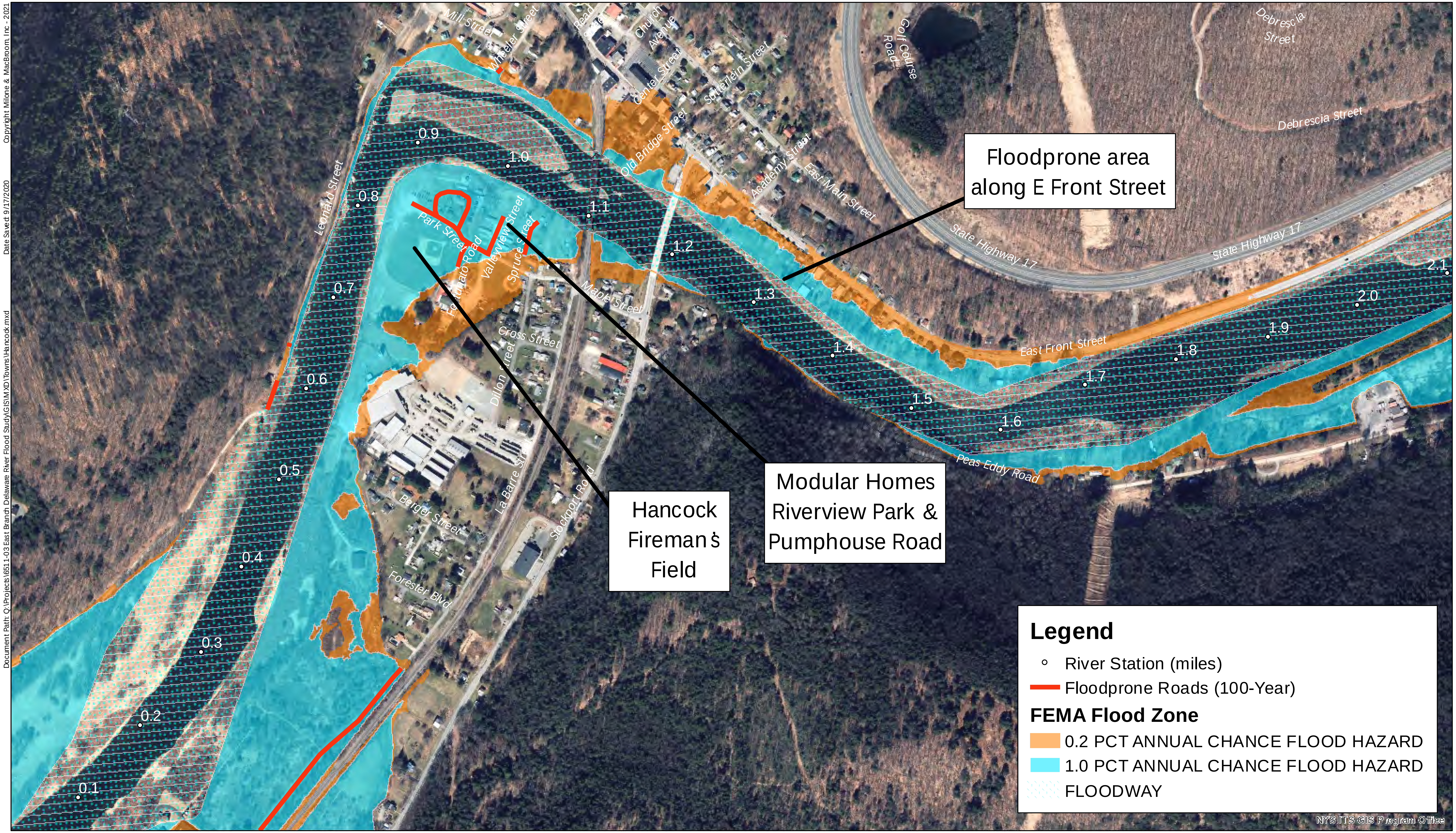
Figure 4-5: 50- and 100-year flood profiles at the Route 97 and NYSW railway bridges in Hancock. Existing and projected future flow scenarios are plotted.

Floodplain reconnection along the EBDR's left bank downstream of the NYSW railroad bridge was assessed for effectiveness. The affected area includes the Fireman's Field and several residential properties off Park and Maple Streets. This was modeled with the existing rail and Stockport Road bridge and under a hypothetical replacement scenario that also included floodplain benching farther upstream. While measurable reductions in flooding extents and depths are possible, they can be affected by the presence or absence of tailwater controls at the confluence with the WBDR, depending on whether and to what degree that river is also flooding. Ultimately, however, the properties that would benefit from the resulting flood mitigation were the same ones that would require acquisition in order to construct such a project. Therefore, it is recommended that residents in these flood prone areas explore relocation or individual floodproofing measures.

Flood-prone parcels have been identified through a Geographic Information System (GIS) analysis as being within the 100- and 500-year floodplains in the Village of Hancock area. In summary, the GIS identified 94 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 724 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional 31 parcels and 10 acres of land.

The 10-year floodplain in this area along the EBDR includes the floodway and a smaller area on the inside (near Park Street) and outside (south of Mill Street) bends of the EBDR. Neither location appears to impact structures. Flooding inundates land on both sides of the EBDR as it approaches the merge with the West Branch, but floodwater does not impact existing structures. Floodwater does, however, cover parts of Labarre Street, and they extend past the road and railroad line to the rear portions of residential properties located along Route 97 at the southern end of the Village.

Photo 4-2
Railroad Bridge over the EBDR in Hancock



HIGH RISK AREA #1 - HANCOCK (EBDR)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-6

0 100 200 400 600 800 1,000 Feet

1 in = 500 feet

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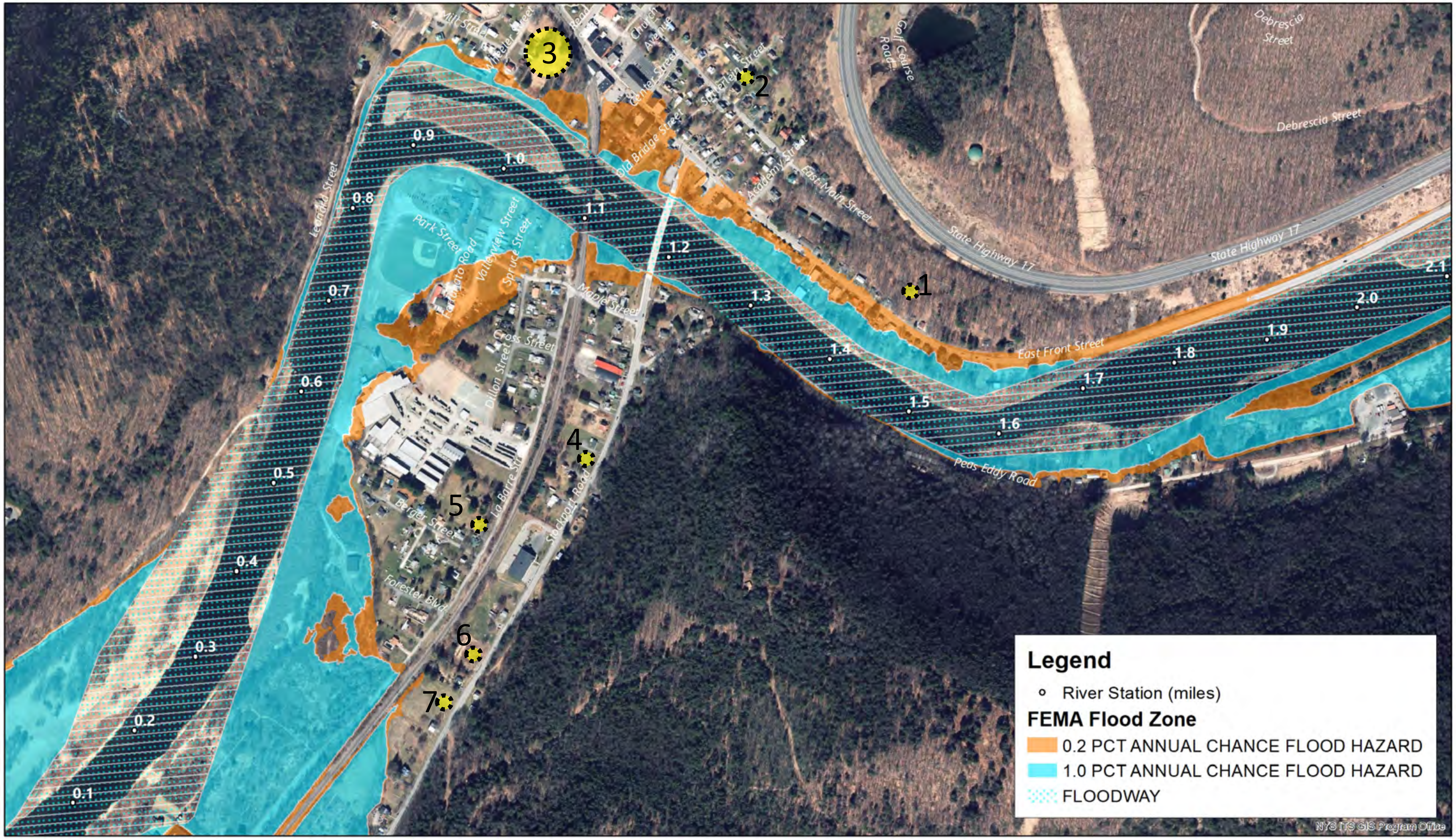
The area subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly in some areas, and depths are increased. Flooding in this area impacts properties on the north side of the East Branch, the island to the west of the railroad and Route 97 bridge, the inside bend of the river (southeast side), and area on the eastern side of the East Branch in close proximity to the confluence with the West Branch. North of the river on the east side of the Village, there are several residential properties within the area subjected to floodwaters during a 100-year flood. On the south side of the river just outside the Village, there are a few residential properties and a larger Wild, Forested, Conservation and Public Parks property within the area subjected to floodwaters during a 100-year flood. Continuing west toward the center of the Village near the Route 97 bridge, the area subjected to floodwaters during a 100-year flood impacts residential and retail uses while on the south and inside bend of the East Branch, the area subjected to floodwaters during a 100-year flood impacts several residential properties and the ball field as well as the mostly undeveloped lumber mill property. South of the mill property, the floodplain extends across LaBarre Street, the railroad tracks, and up to the slope adjacent to Route 97. This area includes several residential properties. The area subjected to floodwaters during a 100-year flood also inundates the peninsula formed by the East and West Branches, but it seems to stop before reaching Meadow Beach Lane.

Figure 4-7 is a relocation master plan for Hancock.

Hancock (East Branch) Conceptual Redevelopment Locations



HIGH RISK AREA #1 - HANCOCK (EBDR)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-7

Potential Residential Relocation Area

Potential Non-Residential Relocation Area

0 100 200 400 600 800 1,000
Feet

1 in = 500 feet

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Hancock (East Branch) Conceptual Potential Redevelopment Locations

Vital Information

Existing conditions & likely scenarios for developing potential relocation areas:

1) 1 parcel consisting of ~1 Acre. Likely Density – Medium (1/2-acre min. lot size). This undeveloped lot has access to East Front Street, however, while the lot is outside the floodplain the road is within the 500-year floodplain which could create accessibility issues during a 500-year flood event.

2) 1 parcel consisting of ~.25 Acres, Likely Density – High (1/4 -acre min. lot size). This lot is undeveloped and could provide for 1 parcel.

3) 32 parcels consisting of ~3.5 Acres. Likely Density – High (1/4-acre min. lot size). This parcel is currently subdivided in to one 2.2 acre lot and 31 0.4 acre lots. It appears it has been subdivided to provide for residential uses, such as mobile homes, but the site is currently undeveloped.

4) 1 parcel consisting of ~1.5 Acres. Likely Density – Medium (1/2-acre min. lot size). One parcel could be provided as infill and still retain acreage for the existing structure on the lot.

5) 1 parcel consisting of ~1 Acre. Likely Density – Medium (1/2-acre min. lot size). One parcel could be provided as infill and still retain acreage for the existing structure on the lot.

6) 1 parcel consisting of ~1 Acre. Likely Density – Medium (1/2-acre min. lot size). Two parcels could be provided on the lot.

7) 1 parcel consisting of ~7 Acres. Likely Density – Medium (1/2-acre min. lot size). There are two existing structures located on this lot. 1-2 parcels could be provided as infill and still retain acreage for the existing structures on the lot.

4.4 High Risk Area #2 – Cadosia

Cadosia is a hamlet located in the town of Hancock where Cadosia Creek meets the EBDR. This is a small crossroads area consisting of residential structures, a few businesses, lodging establishments, and rental cabins. Unlike many of the small communities along the EBDR, Cadosia is situated within the tributary valley rather than upon depositional alluvial features within the EBDR valley. Thus, flooding of the EBDR itself does not pose a direct hazard to most of the hamlet although flooding of Cadosia Creek may still result in substantial damages. Severe ice jamming in 1981 reportedly extended 3 miles up the tributary from the EBDR. Cadosia Creek drains an approximately 18-square-mile watershed, measured at its confluence with the EBDR. Here, the EBDR's watershed covers 820 square miles. Figure 4-8 shows the Cadosia area.

No bridges cross the EBDR at Cadosia although there are several crossings of Cadosia Creek. A floodwall constructed of sheet piling was observed upstream of a bridge carrying Lower Cadosia Road over the creek; it is unknown what level of flood protection this provides. Up-to-date hydraulic modeling is not available for this stream, which would be valuable for assessing sediment transport, bridge hydraulics, flood extents, and mitigation alternatives for the hamlet. According to FEMA modeling of the EBDR, Lower Cadosia Road and Route 268 are both expected to overtop in the 100-year flood.

Two bridges carrying eastbound and westbound traffic on Route 17 cross Route 268/Old Route 17 and Cadosia Creek just upstream from its confluence with the EBDR. Both bridges (BIN 1054891 and 1054892) were constructed in 1967 and are owned by the NYSDOT.

Eleven crossings of Cadosia Creek are included in effective FEMA modeling, dating to 1988. These are listed in Table 4-4. It is recommended that this modeling be updated to accurately reflect the current hydraulic and hydrologic conditions in the watershed. Three crossings of the creek have been replaced since the most recent hydraulic modeling effort; the remaining structures were built in the 1960s and '70s and are likely due for replacement or repair in the near future. This may present an opportunity to reduce the overall number of stream crossings by relocating either the stream, road, or both. This is discussed in the Sands and Cadosia Creek Watershed Assessments (LandStudies 2009). Updated modeling would enable assessment of the effectiveness of these alternatives and facilitate design of appropriately sized structures with adequate countermeasures to withstand the powerful erosive forces of this stream.

TABLE 4-4
Crossings of Cadosia Creek Included in Effective FEMA Modeling
(Bankfull width estimated per USGS SIR 2009-5144)

Road	NBI BIN	Year Constructed	Span (feet) (number of spans)	Bankfull Width (feet)
Route 268/Old Route 17	1063340	1967	82 (1)	48.9
Route 17 Eastbound	1054892	1967	632.9 (6)	48.9
Route 17 Westbound	1054891	1967	626 (6)	48.9
Cadosia Road	2226850	1974	55.1 (1)	48.8
Benedict Road	2226830	1974	54.1 (1)	48.6
Cadosia Road	2226840	1974	55.1 (1)	46.9
Cadosia Road	2267200	2007*	56.1 (2)	45.3
Apex Road/ Route 268	1050530	1965	46.9 (1)	44.4
Apex Road/ Route 268	1050540	1965	41.0 (1)	42.7
Apex Road/ Route 268	1050550	1965	58.1 (2)	42.1
Lang Road	2226810	2006*	35.1 (1)	42.0
Lang Road	2226820	2007*	44.0 (1)	39.6
Apex Road/ Route 268	1050560	1965	42.0 (2)	36.9

*Bridge replaced since most recent detailed FEMA study (1988)

An assessment of the Sands and Cadosia Creek watersheds was conducted in 2009 by LandStudies for FUDR and the Town of Hancock. The study produced a report and conceptual master plan for stream restoration and flood mitigation alternatives along these two watercourses. The report includes detailed analysis of historical land use practices and modifications to the streams and their valleys, identification of priority restoration and repetitive damage areas, and a series of recommendations for restoration and flood resiliency improvements. To assess the effectiveness and to design and construct these conceptual alternatives, hydraulic modeling of Cadosia Creek is necessary.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Residential (200) and Wild, Forested, Conservation Lands & Public Parks (900).

These include the following:

- Residences

Parcels have been identified through a GIS analysis as being within the 100- and 500-year floodplains, respectively, in the Cadosia area. In summary, the GIS identified 45 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 432 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional eight parcels and 115 acres of land.

The 10-year floodplain in this area along the EBDR includes the floodway, lowland areas on the inside (south) bend of the EBDR, and near the mouth of Cadosia Creek. Floodwater also inundates several residential and one commercial property between Peas Eddy Road and the EBDR between the village of Hancock and the bend at Cadosia. There is also some flooding along the Cadosia Creek northwest of the Route 17 bridges.

The areas subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly in some areas, and depths are increased everywhere. At the mouth of the Cadosia Creek, more area is within the floodplain, and floodwaters extend onto a residential property located on DeBrescia Road, adjacent to the Route 17 bridges. Floodwater depth and area covered increase on properties located between Peas Eddy Road and the river as well as on the interior bend of the river just downstream and across the river from the mouth of the Cadosia Creek. On the northern side of the river, the floodwater is generally contained within the floodway due to existing topography.

Figure 4-9 is a relocation master plan for Cadosia.

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HIGH RISK AREA #2 - CADOSIA (EBDR & CADOSIA CREEK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-8

0 100 200 400 600 800 1,000 Feet

1 in = 500 feet

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Cadosia Conceptual Redevelopment Locations

HIGH RISK AREA #2 - CADOSIA (EBDR & CADOSIA CREEK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-9

Potential Residential Relocation Area

Potential Non-Residential Relocation Area

0 100 200 400 600 800 1,000 Feet

1 in = 500 feet

N

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Cadosia Conceptual Potential Redevelopment Locations

Vital Information

Existing conditions & likely scenarios for developing potential relocation areas:

1) 2 parcels consisting of ~170 Acres. Likely Density – Low (1-acre min. lot size) (area just off the map). Some structures are located on one of the parcels but there is significant potential to provide lots along the existing driveway/path that currently cuts through both properties.

2) 1 parcel consisting of ~150 Acres, Likely Density – Low (1-acre min. lot size). This undeveloped parcel is heavily wooded but has cleared areas and an existing drive/path which connects to Cadosia-Apex Road.

3) 2 parcels consisting of ~0.5 Acres. Likely Density – Medium (1/2-acre min. lot size). One parcel could be provided if both undeveloped parcels were utilized.

4) 1 parcel consisting of ~1.5 Acres. Likely Density – Medium (1/2-acre min. lot size). One parcel could be provided as infill and still retain acreage for the existing structure.

4.5 High Risk Area #3 – Fish's Eddy

Fish's Eddy is a hamlet located on the EBDR in the town of Hancock. Fish Creek drains just over 11 square miles as it flows northwesterly to join the EBDR at Fish's Eddy. At this point, the EBDR's watershed is 784 square miles. Tucked into a tight valley on the south, outside bend of the EBDR, this compact community located along Route 28 has access to Route 17 on the northwest side of the river via the Route 28 bridge over the East Branch. Route 28 follows the Fish Creek valley, climbing away from the EBDR to the southeast. Route 28, or Fish Eddy-Sullivan County Line Road, is the only access route to Fish's Eddy that does not parallel the EBDR. Bodoit and O&W Roads are susceptible to damage and have reportedly been washed out during past floods. Route 17 is likely to be the most reliable evacuation and emergency access route so long as the Route 28 bridge over the EBDR is passable. The community consists primarily of residential properties but includes several commercial and industrial properties.

Route 28 crosses the EBDR as a single lane on a three-span through-truss bridge at STA 11.3, originally constructed in 1901 for the O&W Railroad and converted to a highway bridge following abandonment of the rail line in the 1950s (BIN 3352620). The structure is currently owned by Delaware County. FEMA modeling indicates that this bridge contributes to some backwater flooding, but modeled floodwater elevations remain below the low chord of the deck up to the 500-year flood. A historical photograph shows that the "Pumpkin Flood" of 1903 left this bridge with very little freeboard, if any. At its estimated peak discharge at this location, this was roughly a 100-year flood. The road formerly crossed the EBDR just upstream; this can be seen on the right side of the historical photograph. The relic abutments and central pier footing remain in place but are not represented in FEMA modeling. It is recommended that additional channel cross sections be surveyed near these structural features for incorporation into the existing hydraulic model to assess whether these archaic bridge components contribute to flooding in Fish's Eddy.

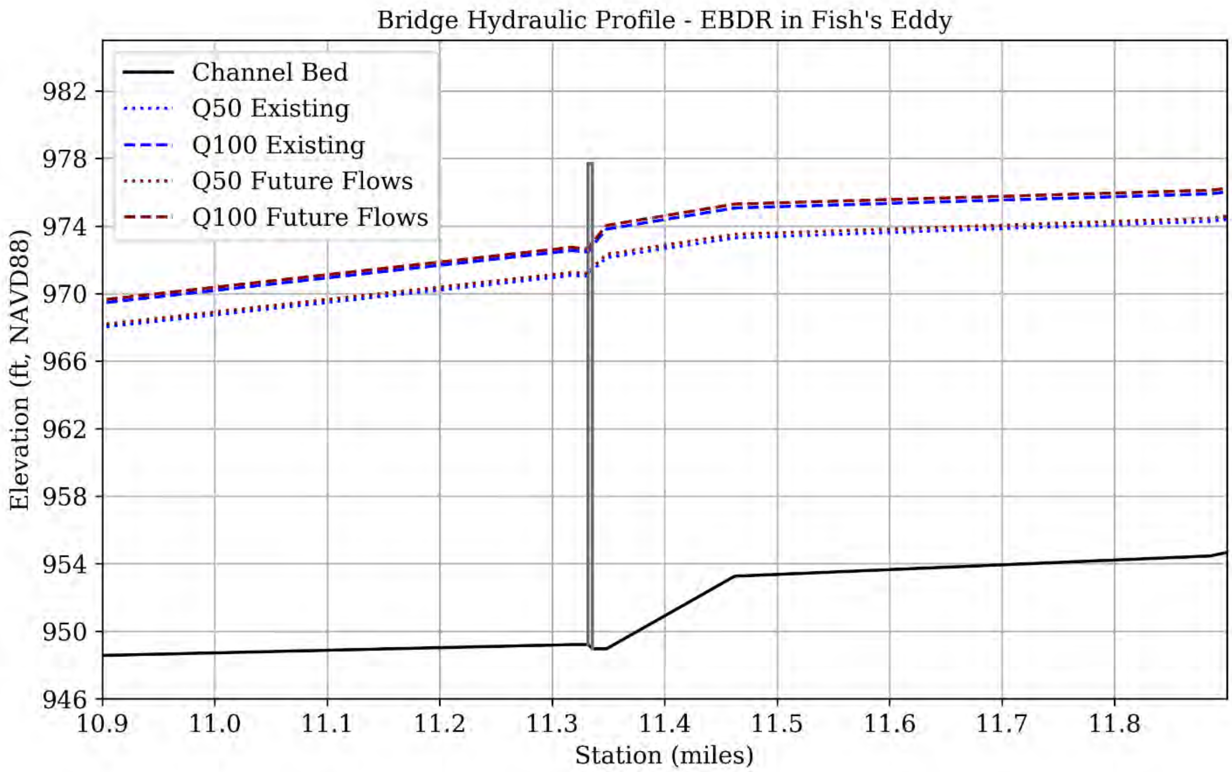


Figure 4-10: 50- and 100-Year Flood Profiles at the Route 28 Bridge in Fish's Eddy. Existing and projected future flow scenarios are plotted.

Just upstream of the Bodoit Road crossing of Fish Creek, the stream is undergoing lateral migration, with an active failure of the left (southern) bank, seen in the photo below. Over time, this realignment may threaten the stability of the Bodoit Road bridge as well as adjacent property. Establishing a riparian buffer with bank-stabilizing plantings may be beneficial in this and other cases of bank erosion and mass failures occurring where shallow-rooted vegetation, such as pasture, directly abuts the stream. Route 28 has several crossings of Fish Creek and its tributaries as it winds up the valley to the southeast.

Photo 4-3
Bank Failure Upstream of Bodoit Road Crossing of Fish Creek

FEMA modeling of the EBDR indicates that the river will overtop Bodoit Road downstream of the Route 28 bridge in a 100-year flood. Coincident flooding on Fish Creek is expected to augment this condition although modern hydraulic modeling of this tributary is not currently available. Effective FEMA hydraulic modeling of Fish Creek dates to 1988 and extends roughly

6,500 feet upstream from the confluence with the EBDR. Updated hydrology and extended hydraulic modeling of Fish Creek would enable detailed analyses of flood-prone areas and assessment of bridge adequacy, and their development is recommended.

Between Fish's Eddy and East Branch, flooding of sections of Old Route 17 and O&W Road are expected in the 100-year flood. While FEMA modeling suggests that the new Route 17 would remain dry in this event, detailed two-dimensional modeling of the EBDR and Beaver Kill in the vicinity of the hamlet of East Branch indicates that sections of this thoroughfare may indeed be inundated in the 100-year flood. In this case, access to many areas along the EBDR would be severely restricted.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Residential (200), Vacant Land (300), Commercial (400), Industrial (700), and Wild, Forested, Conservation Lands & Public Parks (900).

These include the following:

- Lodging
- A lumber mill
- A U.S. Post Office and a Head Start Center
- A cemetery
- Delaware County and town-owned public works properties
- EBDR waterway access

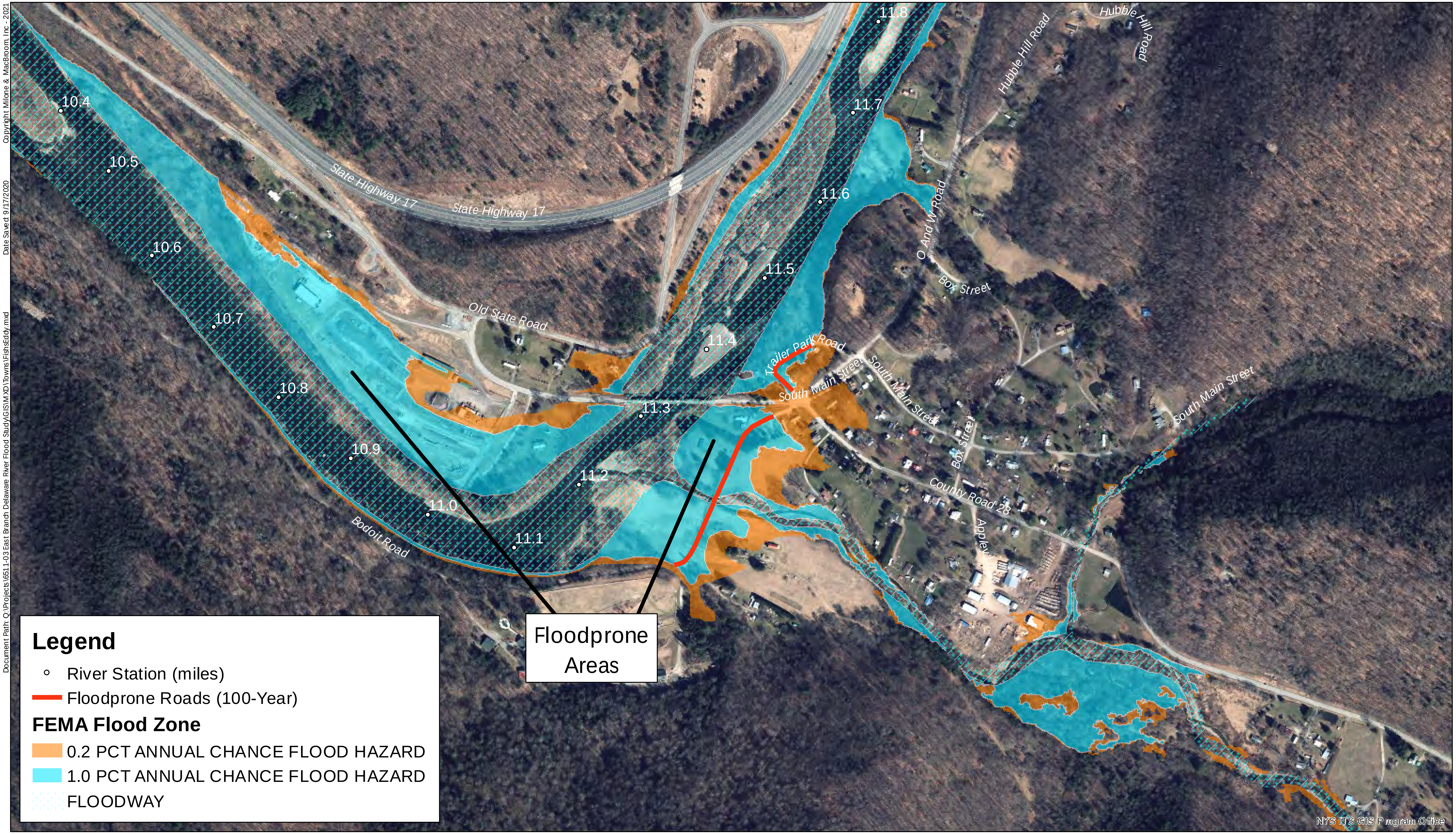
Parcels have been identified through a GIS analysis as being within the 100- and 500-year floodplains, respectively, in the Fish's Eddy area. In summary, the GIS identified 51 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 706 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional nine parcels and 3.5 acres of land.

Photo 4-4
Fish's Eddy in 1903 flood. The railroad bridge is now the single-lane Route 28 bridge. The former road bridge is visible to the right; only substructural features remain today. Courtesy of Colchester Historical Society, Downsville, New York

The 10-year floodplain in this area along the EBRD includes the floodway and mostly undeveloped land in several locations in Fish's Eddy. Residential and undeveloped properties between Bodoit Road and the river in close proximity to Fish Creek are inundated; however, the floodwater does not appear to directly impact structures.

The area subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly in some areas, and depths are increased. The area subjected to floodwaters is somewhat contained within areas immediate to the watercourse; however, the floodplain extends over much of the county-owned and all of the town-owned property on the north side of the EBDR on the inside of the bend in the river. On the south side of the river, flooding impacts properties located in an area formed by the river, the Route 28 bridge property, and property east of Bodoit Road. Flooding in this area impacts several residences and is likely exacerbated by their location adjacent to Fish Creek. Flooding is also an issue along the east side of the river between the Route 28 bridge and Felton Lane, although the flooding does not appear to directly impact structures on the properties. Floodwaters also fill the interior area of the Route 17 southbound on ramp/Old State Road.

Figure 4-11 is an aerial image of Fish's Eddy showing flood-prone areas, including roads and critical facilities. Figure 4-12 is a relocation master plan.



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HIGH RISK AREA #3 - FISH'S EDDY (EBDR & FISH CREEK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-11

0 100 200 400 600 800 1,000
Feet

1 in = 500 feet

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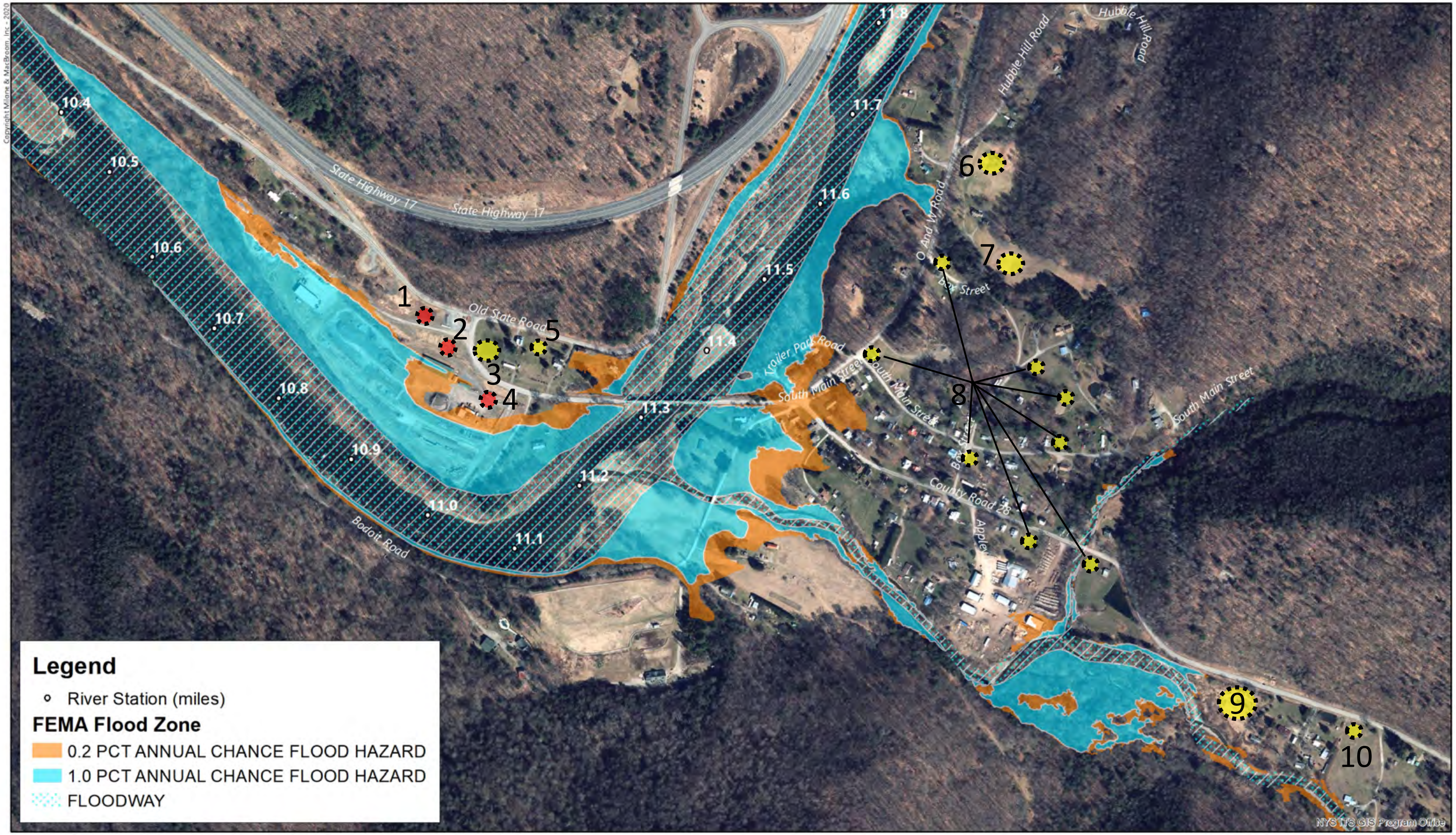
Fish's Eddy Conceptual Redevelopment Locations



HIGH RISK AREA #3 - FISH'S EDDY (EBDR & FISH CREEK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-12

Potential Residential Relocation Area

Potential Non-Residential Relocation Area

0 100 200 400 600 800 1,000
Feet

1 in = 500 feet

N

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Fish's Eddy Conceptual Potential Redevelopment Locations

Vital Information

Existing conditions & likely scenarios for developing potential relocation areas:

1) 1 parcel consisting of ~2 Acres. Likely Density – Low (1-acre min. lot size). This lot is owned by the County and has an existing structure but there appears to be land area available where 1 lot could be created for a non-residential use.

2) 1 parcel consisting of ~1 Acre. Likely Density – Low (1-acre min. lot size). This lot is also owned by the County but does not appear to be part of the developed area used by the County. 1 lot could be created for a non-residential use.

3) 1 parcel consisting of ~1.5 Acres. Likely Density – Medium (1/2-acre min. lot size). One or two lots could be provided and retain a lot for the existing residence.

4) 1 parcel consisting of ~15.5 Acres. Likely Density – Medium (1/2-acre min. lot size). This lot is owned by the State of New York but is mostly undeveloped and could potentially provide lots for non-residential use.

5) 1 parcel consisting of ~1.5 Acres. Likely Density – Medium (1/2-acre min. lot size). This lot has an existing residence but has frontage on two roads which and has the potential to provide 1-2 lots.

6) 1 parcel consisting of ~30 Acres. Likely Density – Low (1-acre min. lot size). Much of the site is heavily wooded but a clearing along O & W Road could provide 1-3 lots.

7) 1 parcel consisting of ~3.5 Acres. Likely Density – Low (1-acre min. lot size). This undeveloped lot is mostly cleared and could provide 2-3 parcels.

8) 6 parcels consisting of ~87 Acres. Likely Density – Medium (1/2-acre min. lot size). These potential infill lots provide an opportunity to provide 6 lots, some on vacant parcels and others on parcels with an existing structure. Two of the lots are large (accounting for 80 acres) but only have a small area that can be easily developed (along existing roads).

9) 1 parcel consisting of 4.5 Acres. Likely Density – Low (1-acre min. lot size). This lot has an existing structure but is mostly undeveloped and could provide 2-3 parcels.

10) 1 parcel consisting of 4 Acres. Likely Density – Low (1-acre min. lot size). This lot has existing structures but has a large undeveloped area that could provide for 1-2 parcels while retaining acreage for the existing structures.

4.6 High Risk Area #4 – East Branch

East Branch is a hamlet located in the town of Hancock at the confluence of the Beaver Kill and the EBDR. The Beaver Kill is the largest tributary to the EBDR, draining 300 square miles, which increases the EBDR's total watershed area from 462 to 762 square miles, an increase of about 65 percent. Because it is unregulated, peak-flood discharge rates are often greater on the Beaver Kill than the EBDR despite its smaller drainage area. The East Branch Fire Station is located in the hamlet, as is Johnston & Rhodes Bluestone, one of the largest employers in the town of Hancock.

The hamlet of East Branch is partially protected from flooding and ice jam rafting by an approximately 1-mile-long earthen levee. The structure was built by the USACE between 1971 and 1972, after which NYSDEC became responsible for its operation and maintenance; it is up to 15 feet high. While originally constructed to prevent rafts of ice from damaging East Branch, it has served to protect the hamlet from flooding as well. This includes protecting the hamlet from the recent floods in 1996, 2004 to 2006, and 2011, although the levee was reportedly "inches" from overtopping in the 2006 flood. FEMA modeling indicates that sections of the embankment will overtop in the estimated 50-year flood. This levee is not a FEMA-accredited flood control structure, so the "dry" side of the levee is still considered to be within the SFHA. It has been proposed to raise the levee by 4 feet in order to provide freeboard over the BFE established in the 2012 FIS. This would presumably also involve extending the eastern end of the levee to tie into high ground at this elevation. FEMA has extensive and stringent design, materials, construction, drainage, inspection, and maintenance standards for levee accreditation (see inset). In East Branch, there may be additional regulatory challenges due to the location of FEMA's regulatory floodway.

Levees and FEMA Accreditation

- FEMA accreditation of the design and construction of a levee is required for remapping of flood zones and reduction of flood insurance rates.
- A FEMA-accredited levee has rigorous design and maintenance requirements, including the following:
    - Freeboard (minimum 3 feet above BFE)
    - Closure devices at all openings
    - Embankment protection
    - Embankment and foundation stability analyses
    - Settlement analyses
    - Interior drainage (may require gravity outlets or pumps)
    - Maintenance plan
    - Operation plan
        - Flood warning system
        - Plan of operation
        - Periodic operation of closure devices
- Additional challenges due to professional liability exposure for design engineers (see National Society of Professional Engineers [NSPE] Position Statement No. 07-1771)

It is always possible for a flood to exceed the design standards of any levee.

The community is primarily residential but included a U.S. Post Office, two locally owned businesses, and two churches. On the north side of the Beaver Kill are a few residential properties, located adjacent to Route 17 on Old State Road is the East Branch Motel, and along Route 30 just to the north along the East Branch is a gas station. Much of the hamlet is expected to flood in the 100-year event, which is modeled as overtopping the existing levee; most of the properties not subject to flooding are located on the elevated terrace south of Fish Road and along Signor Road. Just upstream of its confluence with the Beaver Kill, the EBDR is modeled as flooding Route 30, Old Route 17, and the westbound onramp to the new Route 17 in the base flood. It is possible for access to East Branch to be severely limited if flooding on the Beaver Kill damages or overtops O&W Road and old Route 17, as it is expected to in its 100-year flood.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Residential (200), Vacant Land (300), Commercial (400), and– Industrial (700).

These include the following:

- Religious Institutions
- A U.S. Post Office
- Lodging (between the Beaver Kill and Route 17)
- A gas station (located along Route 30, which is listed as residential most likely due to the residence on the property likely being classified as the primary use)

Photo 4-5
Portion of aerial photograph acquired in July of 1958, prior to construction of the East Branch levee and the new Route 17. Note the Bridge Street bridge has been relocated since this time. Retrieved from the USGS Earth Resources Observation and Science Center's *EarthExplorer* online service.

Flood-prone parcels have been identified through a GIS analysis as being within the 100- and 500-year floodplains, respectively, in the East Branch area. In summary, the GIS identified 116 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 531 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional six parcels and 26 acres of land.

The 10-year floodplain in this area along the EBDR includes the floodway, islands, and lowland areas jutting into the river. Floodwaters inundate the residential property along Route 30 adjacent to the Route 17 bridge over Route 30 and land on the south side of the river, including several residential properties.

The area subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly in some areas, and depths are increased. The majority of the hamlet is located within the area subjected to floodwaters during a 100-year flood. Properties located south of Bridge Street on the south side of the EBDR between the river and a line generally along Fish Road and Signor Road are within the area subjected to floodwaters during a 100-year flood. The hotel, residence, and gas station are also located within the area subjected to floodwaters during a 100-year flood. Properties generally north of Bridge Street, south of the East Branch/Beaver Kill, are located outside the area subjected to floodwaters during a 100-year flood. Sections of both NY Route 17 and Old Route 17 in and around East Branch are expected to be impassable due to inundation in the 100-year flood.

There are four bridges in the hamlet of East Branch. The Old and New Route 17 bridges span the EBDR between STA 16.2 and STA 16.4, immediately upstream of the confluence with the Beaver Kill, which itself is spanned by the Bridge Street bridge. The New Route 17 bridges (BIN 1013451 and BIN 1013452) were constructed in 1961; the Old Route 17 bridge (BIN 1061170) was replaced in 2011. All three are owned by the NYSDOT. FEMA modeling indicates that the Old Route 17 bridge acts as a hydraulic constriction and that the New Route 17 bridge compounds upon the backwater that results. However, the new Old Route 17 bridge is not reflected in effective FEMA modeling. Substructural elements of these bridges were included in two-dimensional hydraulic modeling of the area, and this condition appears to have improved.

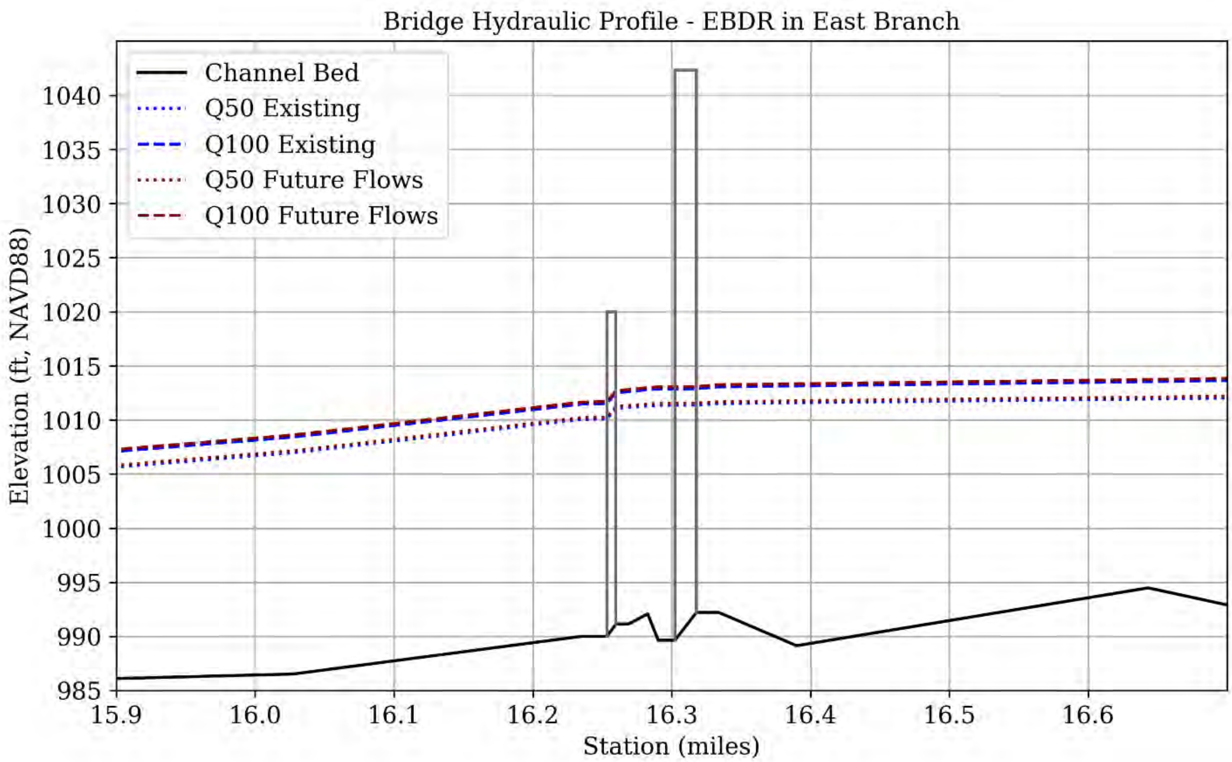


Figure 4-13: 50- and 100-year flood profiles at the old and new Route 17 bridges across the EBDR in East Branch. Existing and projected future flow scenarios are plotted.

The Bridge Street crossing of the Beaver Kill (BIN 3352660) was constructed in 1932 and is owned by Delaware County. The bridge acts as a moderate hydraulic constriction and may result in increases in upstream flooding depths by up to about 2 feet in the 100-year flood. Under certain specific circumstances, it may be possible for backwaters caused by the bridge to result in the upstream portion of the East Branch levee overtopping when it otherwise would not have. About 2 miles upstream on the Beaver Kill, a relic bridge pier is present just downstream of the Trout Brook confluence in the small hamlet of Peakville. It is recommended that this structure be assessed for its influence on flow dynamics, specifically regarding whether it contributes to bank erosion that threatens O & W Road.

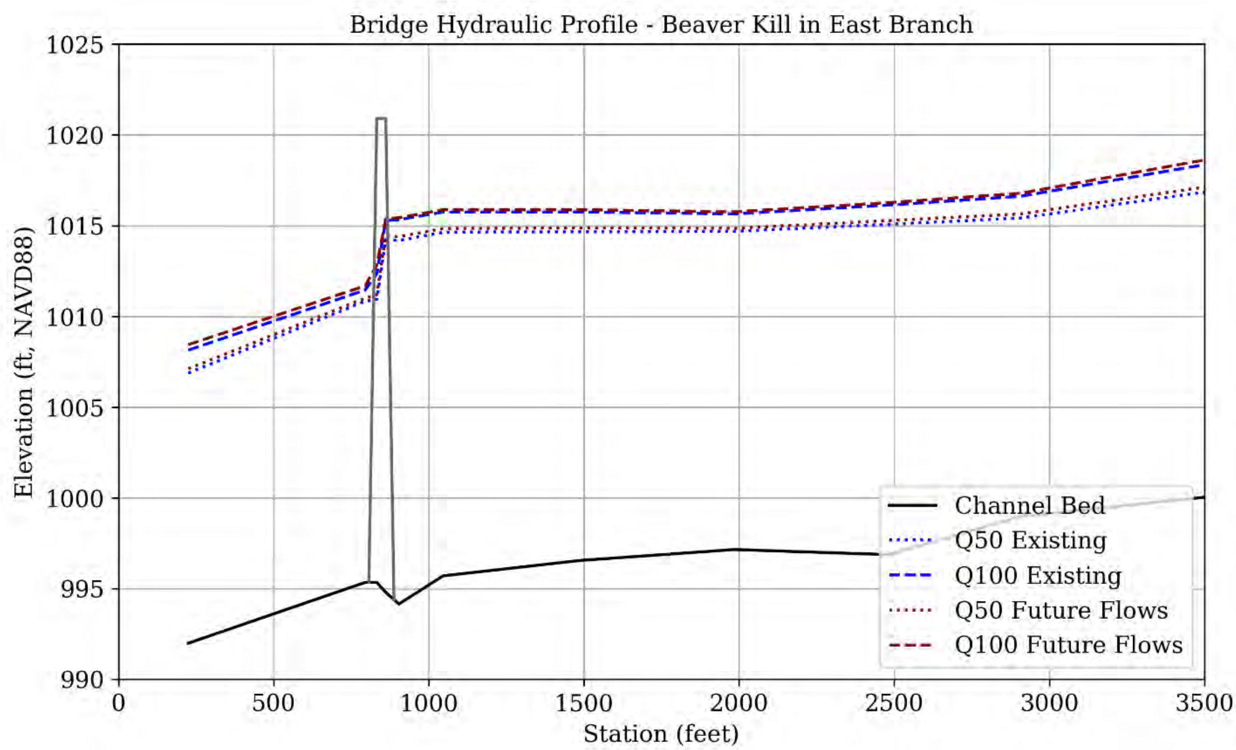


Figure 4-14: 50- and 100-year flood profiles at the Bridge Street bridge across the Beaver Kill in East Branch. Existing and projected future flow scenarios are plotted.

Photo 4-6
Levee in East Branch. View is from the levee crest, roughly to the southeast. Ponding area is out of frame to the photographer's right. EBDR is to the left. Outlet culvert with flap gate is behind photographer.

FEMA modeling of the Beaver Kill does not account for potential tailwater controls that may present when both it and the EBDR are flooding. For a given discharge on either the Beaver Kill or the EBDR, the resulting water surface elevations in East Branch can vary, depending on whether just one, the other, or both rivers are flooding. The relative magnitude and timing of flooding on each river can also affect flooding in East Branch. To assess these impacts on flooding in East Branch, a two-dimensional unsteady-state hydraulic model was developed for approximately 2 miles of the Beaver Kill and 4 miles of the EBDR surrounding the two rivers' confluence. Flow hydrographs of recent major floods have been recorded at the EBDR gauges at Harvard (just upstream) and Fish's Eddy (just downstream) and the Beaver Kill gauge, about 10 miles upstream at Cooks Falls. These records were used to develop unsteady flow boundary conditions for modeling of flood events in 1996, 2000, 2004, 2005, 2006, and 2011. Synthetic design flow hydrographs were developed to assess flooding in the 10-, 25-, 50-, 100-, and 500-year events. Model calibration and validation were possible thanks to high-water marks surveyed by the USGS following the 2004 and 2006 floods (USGS OFR 2005-1166; USGS OFR 2009-1063). Modeled peak-water surface elevations were accurate to ±0.5 feet at all but one of the eight surveyed high-water marks that fall within the model domain.

Anecdotal reports confirm modeled results in these and other recent floods, and the levee was very nearly overwhelmed in the 2006 flood. The Pepacton Reservoir attenuated peak flows on the EBDR in this event by approximately 23 percent, despite the fact that the impoundment was at 101 percent capacity and spilling at the inception of the flood (USGS OFR 2009-1063). Without such a reduction in peak discharge, the hamlet of East Branch would almost certainly have been devastated by this flood. Hydraulic modeling indicates that the nonattenuated discharge on the EBDR would have resulted in the levee overtopping as well as flows entering the hamlet area from the unprotected east end. Figure 4-15 illustrates the moderating influence of the reservoir even this far downstream. The ratio of total volume discharged by the EBDR and Beaver Kill over the event is comparable and fairly proportional to the difference in watershed area: 125,700 acre-feet on the EBDR at Harvard and 90,400 acre-feet on the Beaver Kill at Cooks Falls. Nevertheless, peak discharge on the Beaver Kill was roughly three times greater than on the EBDR due in large part to the Pepacton Reservoir. A similarly sharp, concentrated flood wave on the EBDR may have resulted in far more damage, both upstream and downstream of East Branch.

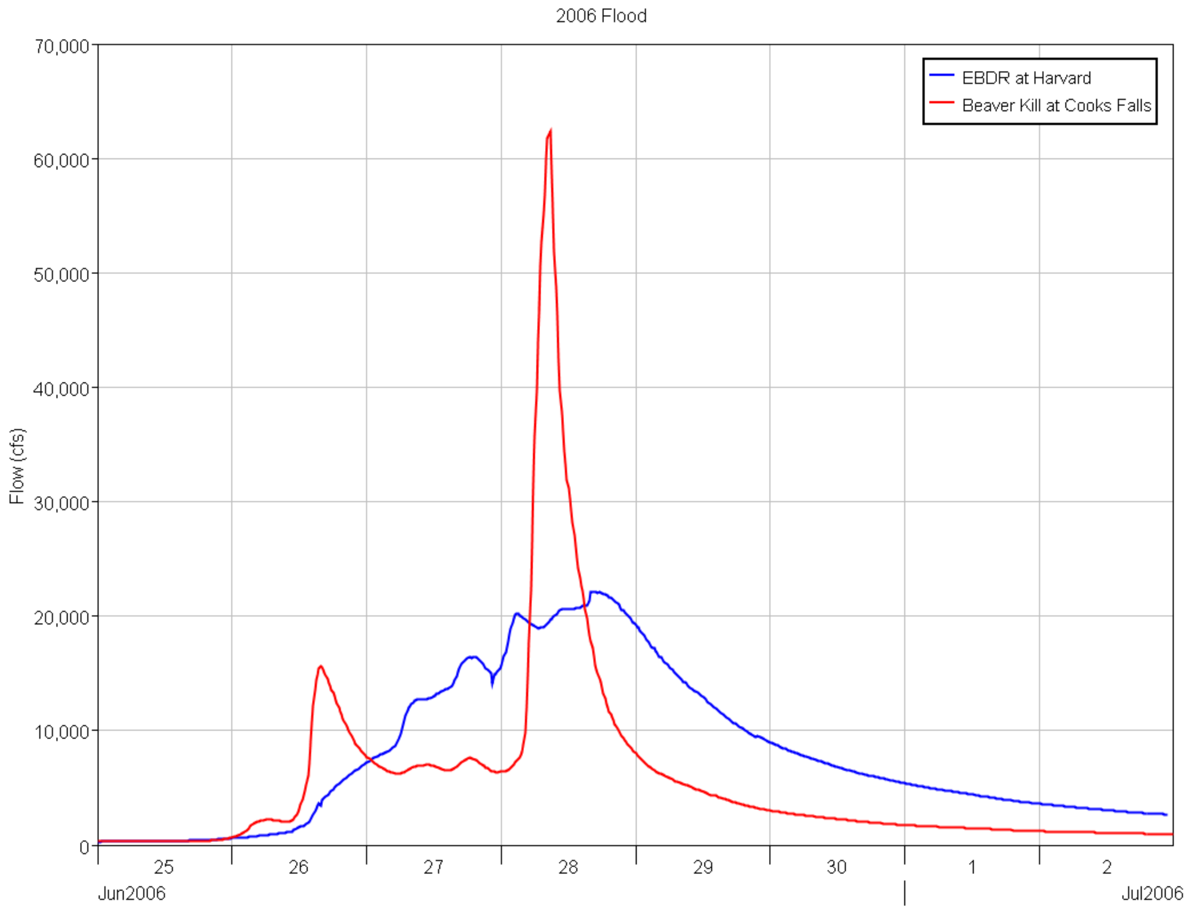


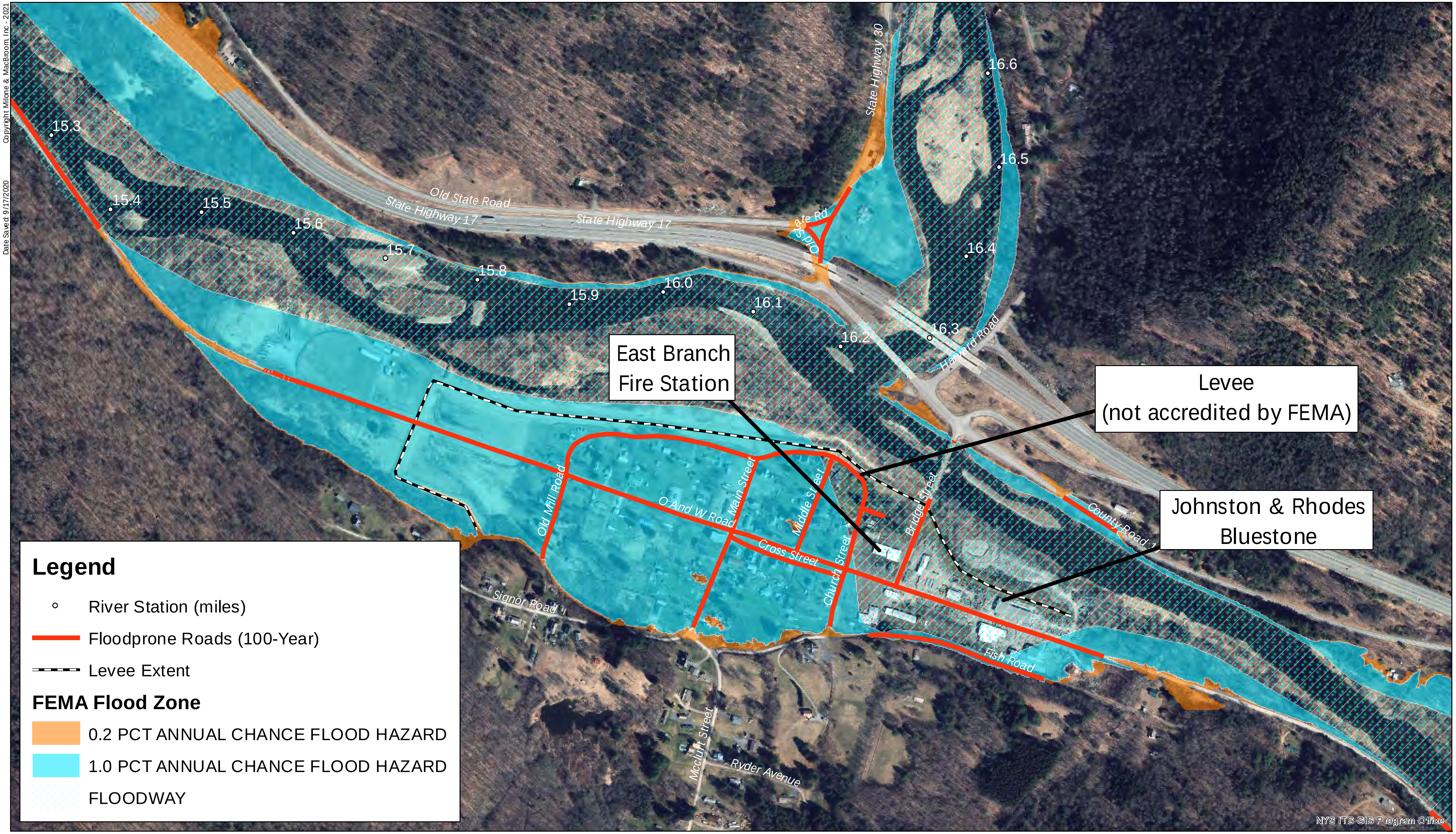
Figure 4-15: Comparison of EBDR Flows Gauged at Harvard (blue) and Beaver Kill Flows Gauged at Cooks Falls (red) during the 2006 flood

The total volume that each river discharges during the flood is comparable, but while much of the Beaver Kill's unregulated flow passes through in less than 24 hours, flooding on the EBDR is dispersed over a few days but with a considerably diminished peak.

Proposed improvements to the levee were incorporated into this model to assess the potential impacts. Results indicate that elevating the levee by approximately 4 feet would provide flooding protection in coincident 100-year floods on the EBDR and Beaver Kill, provided it is otherwise capable of withstanding such an event. This includes the crucial tie-in of the levee to high ground at its eastern extent. However, the structure is modeled as being overwhelmed in a 500-year flood. This project requires placing fill within the FEMA regulatory floodway, which, by definition, would be expected to cause a rise in BFE on the Beaver Kill and EBDR.

Figure 4-16 is an aerial image of the East Branch showing flood-prone areas, including roads and critical facilities. The location of the levee is indicated.

Figure 4-17 is a relocation master plan for East Branch.



HIGH RISK AREAS #4 - EAST BRANCH (EBDR & BEAVER KILL)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-16

0 100 200 400 600 800 1,000
Feet

1 in = 500 feet

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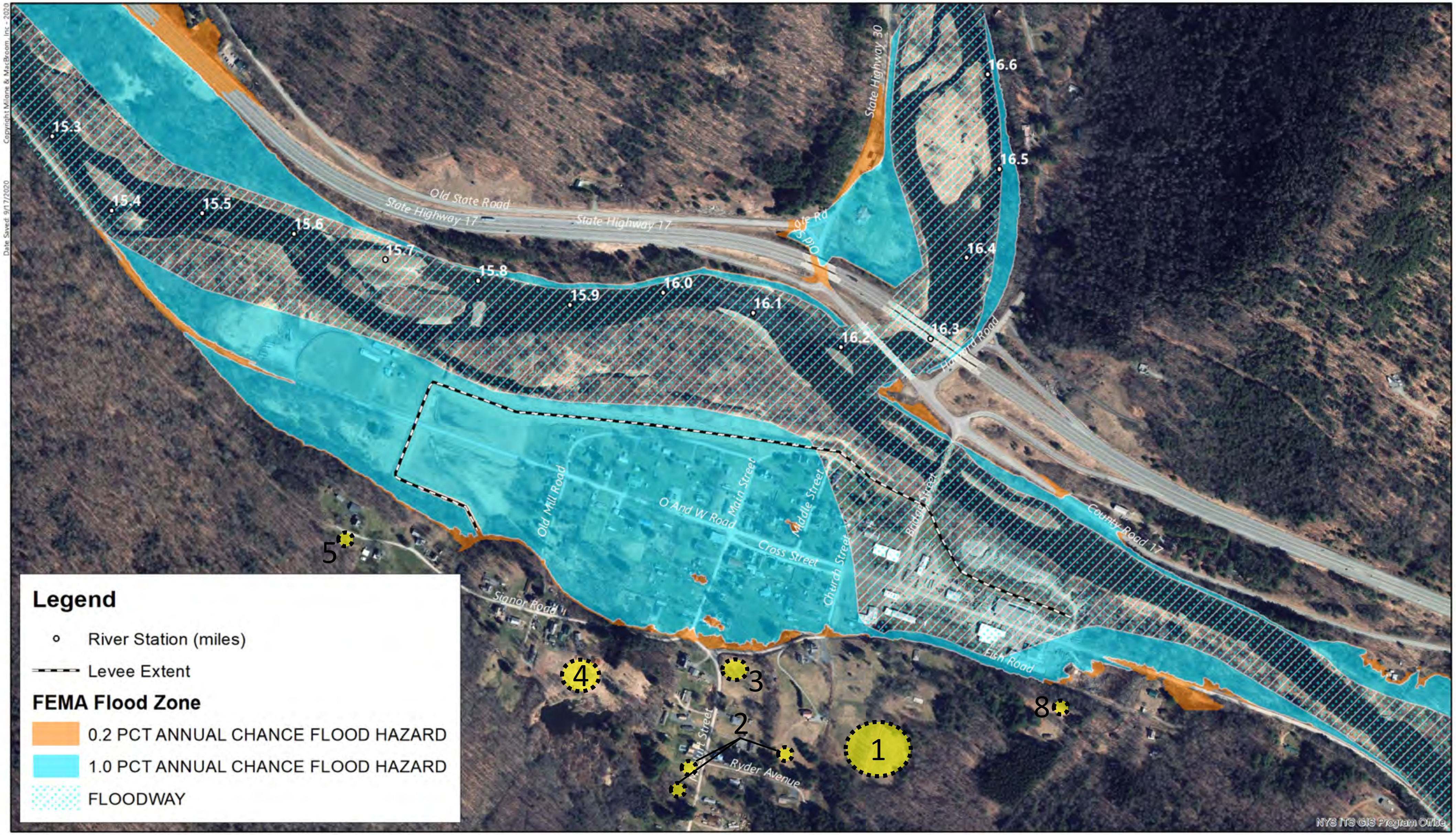

HIGH RISK AREAS #4 - EAST BRANCH (EBDR & BEAVER KILL)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-17

Potential Residential Relocation Area
Potential Non-Residential Relocation Area

0 100 200 400 600 800 1,000
Feet
1 in = 500 feet

N

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East Branch Conceptual Potential Redevelopment Locations

Vital Information

Existing conditions & likely scenarios for developing potential relocation areas:

1) 2 parcels consisting of ~19 Acres. Likely Density – Low (1-acre min. lot size). One lot is landlocked and would require access through an adjacent lot. The larger parcel is heavily wooded and has access to Fish Road. There are clearings on both lots which could provide for 2-3 lots.

2) 3 parcel consisting of ~8 Acres. Likely Density – High (1/4 Acre- 1/2-acre min. lot size). The three infill lots include two undeveloped lots and one lot with an existing residence that could provide 3-4 parcels.

3) 1 parcel consisting of ~2.5 Acres. Likely Density – High (1/4 Acre- 1/2-acre min. lot size). This is an undeveloped lot on Main Street could provide 3-4 parcels.

4) 1 parcel consisting of ~65 Acres. Likely Density – Medium (1/2-acre min. lot size). This lot an an existing structure and much of the it is wooded. The portion of the lot closest to the road could provide for 2-3 parcels.

5) 1 parcel consisting of ~48 Acres. Likely Density – Low (1-acre min. lot size). This lot is at the end of Signor Road and is heavily wooded. 1-2 parcels could be provided adjacent to the road. More parcels could be provided, however, it would require significant tree removal.

4.7 High Risk Area #5 – Harvard

Harvard is a hamlet located in the town of Hancock at the confluence of the EBDR and Baxter Brook. The Baxter Brook watershed encompasses approximately 14 square miles to the north of the EBDR. Measured at Harvard, the EBDR drains 458 square miles. The USGS has operated a stream flow gauge at Harvard (01417500) from 1934 to1967 and from 1977 to the present day.

This community is located along Route 30 at the intersection with Houck Mountain Road. This small, primarily residential community has a few nonresidential uses and vacant land, some of which appears to be farmland. As noted below, the Harvard Road bridge over the East Branch is currently closed, cutting off direct access to Route 30 for properties on the southeast side of the East Branch. The closest connection to other roads is 2.5 miles south where Harvard Road intersects with Route 17, which provides access to Route 30.

Figure 4-19 is an aerial image of Harvard showing flood-prone areas, including roads.

The two-span truss bridge at Harvard is currently closed to vehicular traffic but is still passable to pedestrians (BIN 3352730). It is owned by Delaware County. This is the only crossing of the EBDR in the hamlet and, as such, has value despite the limitations on its use. FEMA modeling indicates that this bridge is adequate for the 10-year flood, although the approach roadway is anticipated to overtop in the 50- and 100-year floods, with the bridge deck overtopping in the 500-year flood. Because of the substantial overtopping relief experienced by this bridge, it does not appear to act as a significant constriction and does not appreciably impact flood elevation profiles. It is recommended that routine inspections of the bridge be performed, and the structure should be removed or replaced if there are indications it may fail during a flood event.

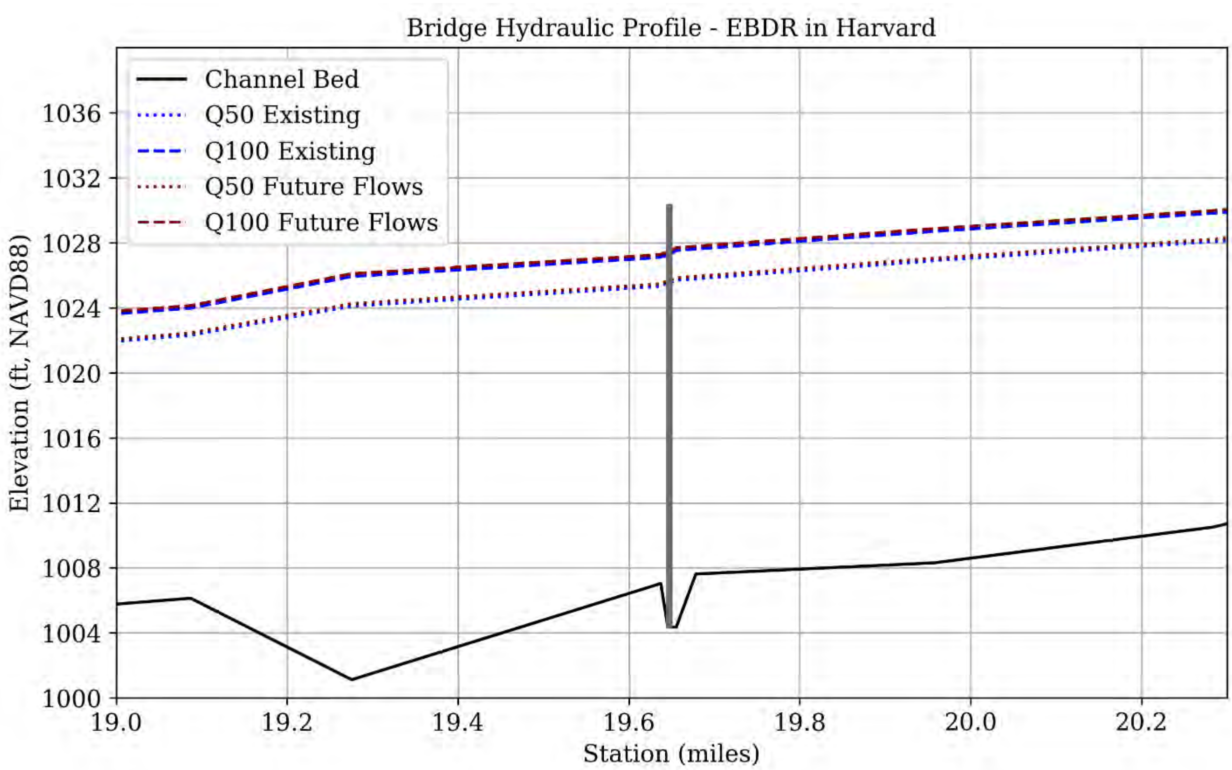


Figure 4-18: 50- and 100-year flood profiles at the Harvard Road bridge across the EBDR in East Branch. This bridge is closed to vehicles. Existing and projected future flow scenarios are plotted.

According to approximate methods FEMA mapping, the Route 30 bridge (BIN 1020760) at STA 19.65 appears to constrict flood flows on Baxter Brook. This bridge was constructed in 1949 and is owned by the NYSDOT. It is recommended that detailed hydraulic modeling be developed for Baxter Brook in order to accurately assess flood hazards in Harvard.

Harvard is susceptible to being cut off from assistance during severe flooding events. Route 30 may be overtopped or damaged by flooding on the EBDR, Baxter Brook, or Morrison Brook. Baxter Brook may also wash out Houck Mountain Road, potentially leaving residents on the right/north bank of the EBDR stranded. On the left/west bank of the river, the only vehicular access is via Harvard Road to and from East Branch. The Harvard Road bridge is open to pedestrians only.

Houck Mountain Road, Gee Brook Road, and Carcass Brook Road cross Baxter Brook and its tributaries in several locations in the valley north of Harvard. Flooding along Baxter Brook and potential mitigation strategies can be informed by updated hydraulic modeling of the stream.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Residential (200), Vacant Land (300), and Community Services (500).

These include the following:

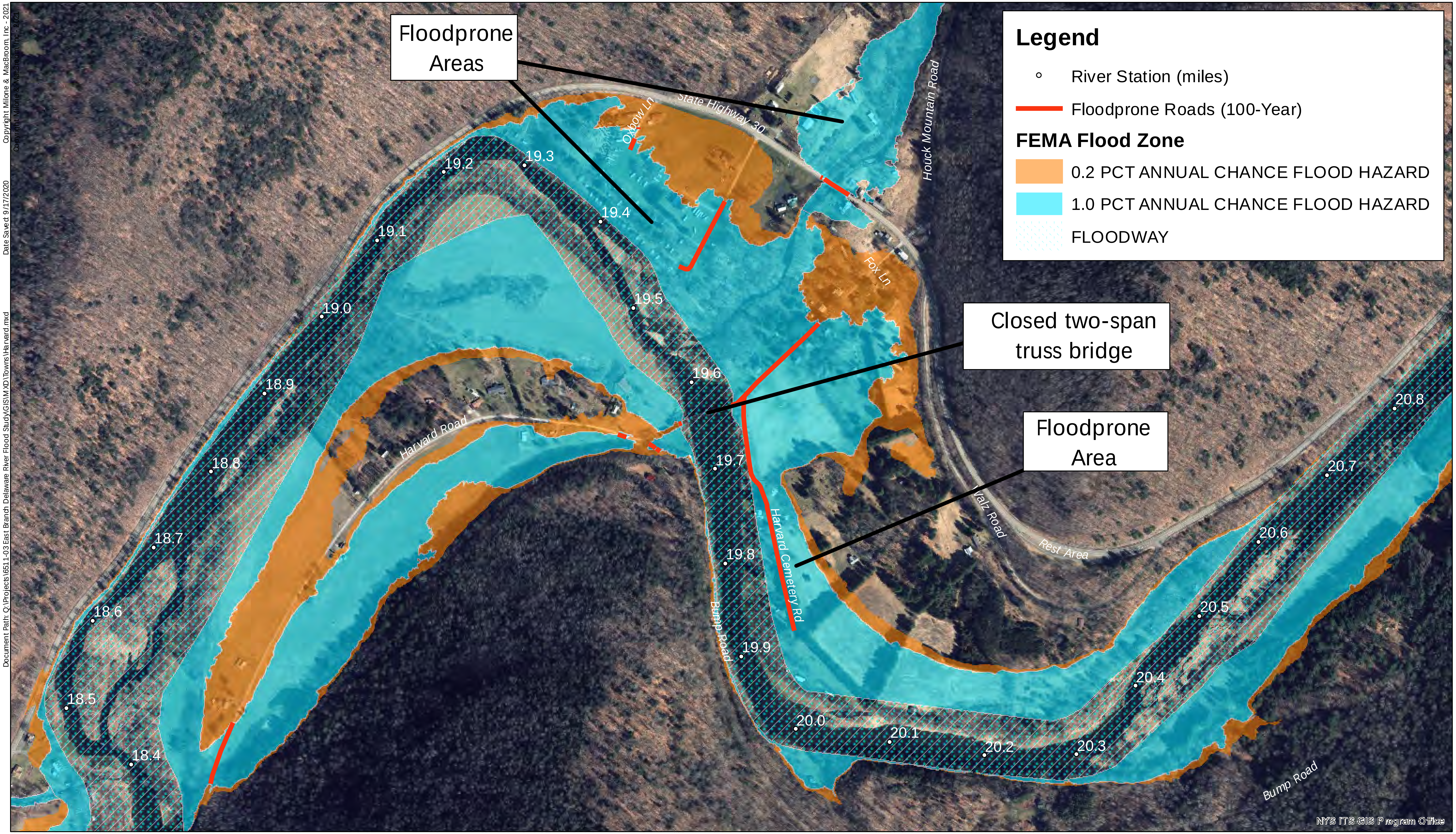
- Campground
- Specialty camp
- Cemetery
- Lodging

Flood-prone parcels been identified through a GIS analysis as being within the 100- and 500-year floodplains, respectively, in the Harvard area. In summary, the GIS identified 66 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 3,355 acres (two parcels contain a total of 2,992 acres) within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional four parcels and 4 acres of land.

The 10-year floodplain in this area along the EBDR includes the floodway and undeveloped property at the mouth of the Baxter Brook and adjacent to the campground as well as undeveloped property on the inner and outer bends of the river, with the most significant floodplain area being located in close proximity to the mouth of the Morrison Brook on both sides of the river.

The area subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly in some areas, and depths are increased. The inside bend of the East Branch on the north and south sides of each bend are within the area subjected to floodwaters as well as much of the residential area generally between Harvard Road and east of Oxbow Lane up to Route 30. Route 30 is not within the area subjected to floodwaters during a 100-year flood. On the north side of the East Branch, several residential properties, the cemetery, and campsite are within the 100-year floodplain. On the south side of the East Branch, homes on the west side of Harvard Road (between the road and the East Branch) are outside the floodplain while two residential properties on the east side of Harvard Road are within the 100-year floodplain.

Figure 4-20 is a relocation master plan for Harvard.



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Date Saved: 9/17/2020
Document Path: Q:\Projects\6511-03 East Branch Delaware River Flood Study\GIS\MXD\Towns\Harvard.mxd

HIGH RISK AREA #5 - HARVARD (EBDR & BAXTER BROOK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-19

0 100 200 400 600 800 1,000
Feet

1 in = 500 feet

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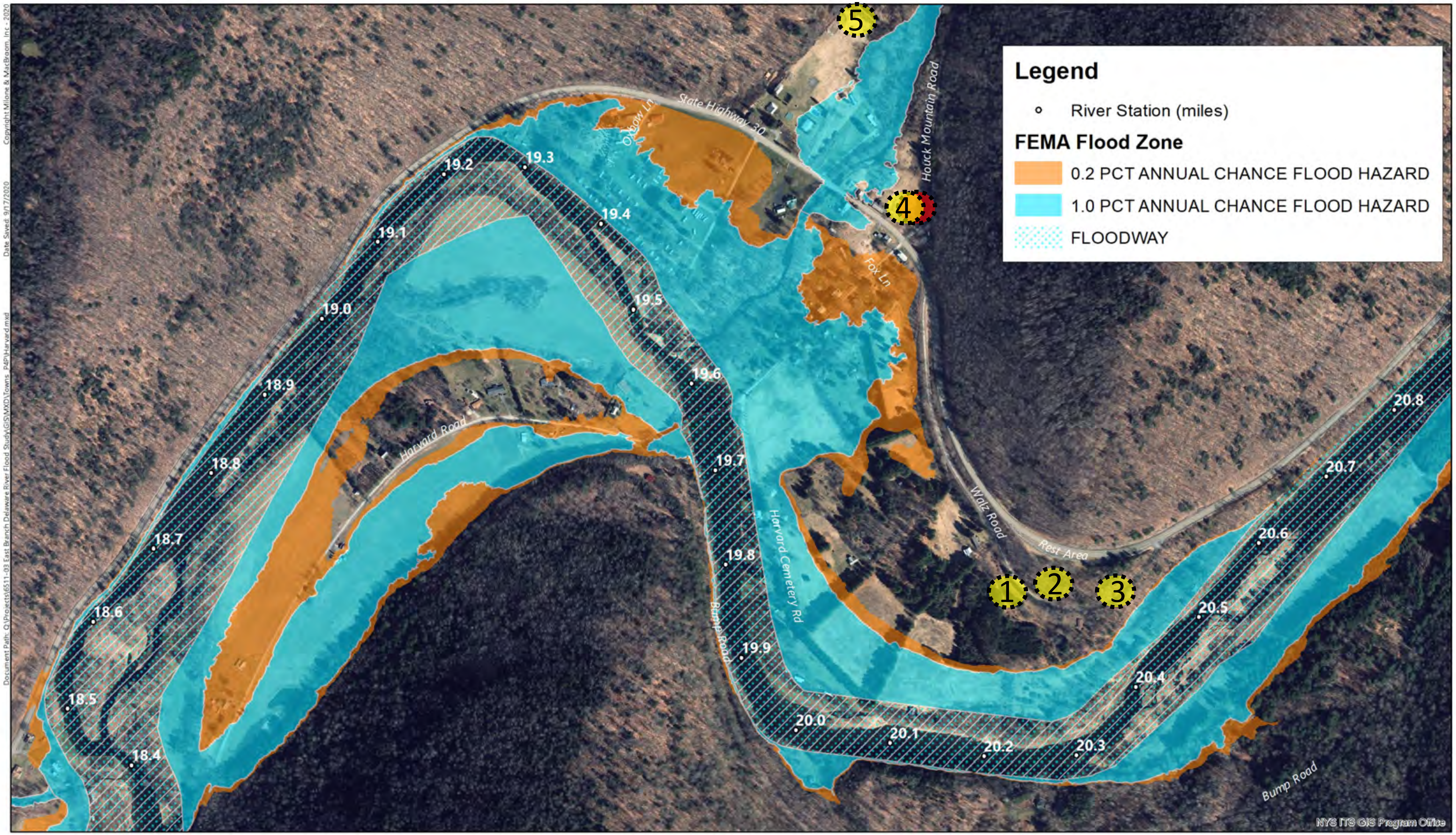

HIGH RISK AREA #5 - HARVARD (EBDR & BAXTER BROOK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-20

Potential Residential Relocation Area
Potential Non-Residential Relocation Area

0 100 200 400 600 800 1,000
Feet
1 in = 500 feet

N

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Harvard Conceptual Redevelopment Locations

Harvard Conceptual Potential Redevelopment Locations

Vital Information

Existing conditions & likely scenarios for developing potential relocation areas:

1) 1 parcel consisting of 161 Acres. Likely Density – Low (1-acre min. lot size). A total of 2-3 parcels could be subdivided along Walz Road.

2) 1 parcel consisting of ~51 Acres. Likely Density – Low (1-acre min. lot size). This is a large lot with most land on the north side of Route 30 – development is not proposed here. Between Route 30 and Walz Road the lot includes several acres that could provide 2-3 parcels.

3) 1 parcel consisting of ~7Acres,. Likely Density – Low (1-acre min. lot size). This narrow long lot along Walz Road could provide 1-2 parcels.

4) 1 parcel consisting of ~2 Acres. Likely Density – Medium (1/2-acre min. lot size). This corner lot with an existing barn and land that has low brush but does not appear to be actively farmed on Route 30 and Houck Mountain Road could provide 3-4 parcels.

5) 1 parcel consisting of ~267 Acres. Likely Density – Low (1-acre min. lot size). This large lot is mostly woodlands and steeper slopes but there are cleared areas and areas of thinner woodlands that could provide for a 1-2 parcels if a shared road or driveway along the narrow strip of land to Route 30 (labeled as White Birch Lane) was feasible as the connection to Route 30.

4.8 High Risk Area #6 – Shinhopple

Shinhopple is a hamlet located on the EBDR in the town of Colchester. Development in the hamlet is limited; along with several residences and a sand and gravel business, many of the buildings in Shinhopple are campers or RVs and cabins at campgrounds in flood-prone areas along the EBDR.

Trout Brook drains a 13-square-mile watershed, emptying into the EBDR near the apex of an especially high-amplitude meander bend. Measured at Shinhopple, the EBDR watershed covers a 422-square-mile area.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Residential (200), Vacant Land (300), Commercial (400), and Community Services (500).

These include the following:

- Lodging
- Campground
- Sand and gravel business

Figure 4-22 is an aerial image highlighting flood-prone areas in Shinhopple.

River Road crosses the EBDR immediately upstream of the confluence with Trout Brook at STA 25.7 (BIN 3352030). This bridge is owned by Delaware County. Trout Brook appears to be causing damage to the approach roadway embankment as it runs parallel between Route 30 and the EBDR. The current River Road bridge was constructed in 1992 and is sited at the location of an older crossing, and the remains of what appears to be a concrete pier or other substructural element are roughly in the center of the right (northern) span of the existing bridge. This large concrete block is prone to snagging debris and encourages sediment deposition underneath the bridge, and exploring the feasibility of its removal is recommended. Fill, including large quarried stones, extends across between one third to one half of the southern span of the bridge. The purpose of this material is not clear, although it may have been placed to address alignment issues with a side channel of the EBDR. The hydraulic opening of this bridge has been significantly reduced, and removal of archaic bridge components and unnecessary obstructions to flow is recommended.

Photo 4-7
Log drive raft in Shinhopple. Courtesy of Colchester Historical Society, Downsville, New York

FEMA modeling indicates that the River Road bridge is undersized and acts as a moderate hydraulic constriction. The bridge does not overtop in the FIS model flood profiles, although the EBDR reaches the structure's low chord in the 50-year and greater floods.

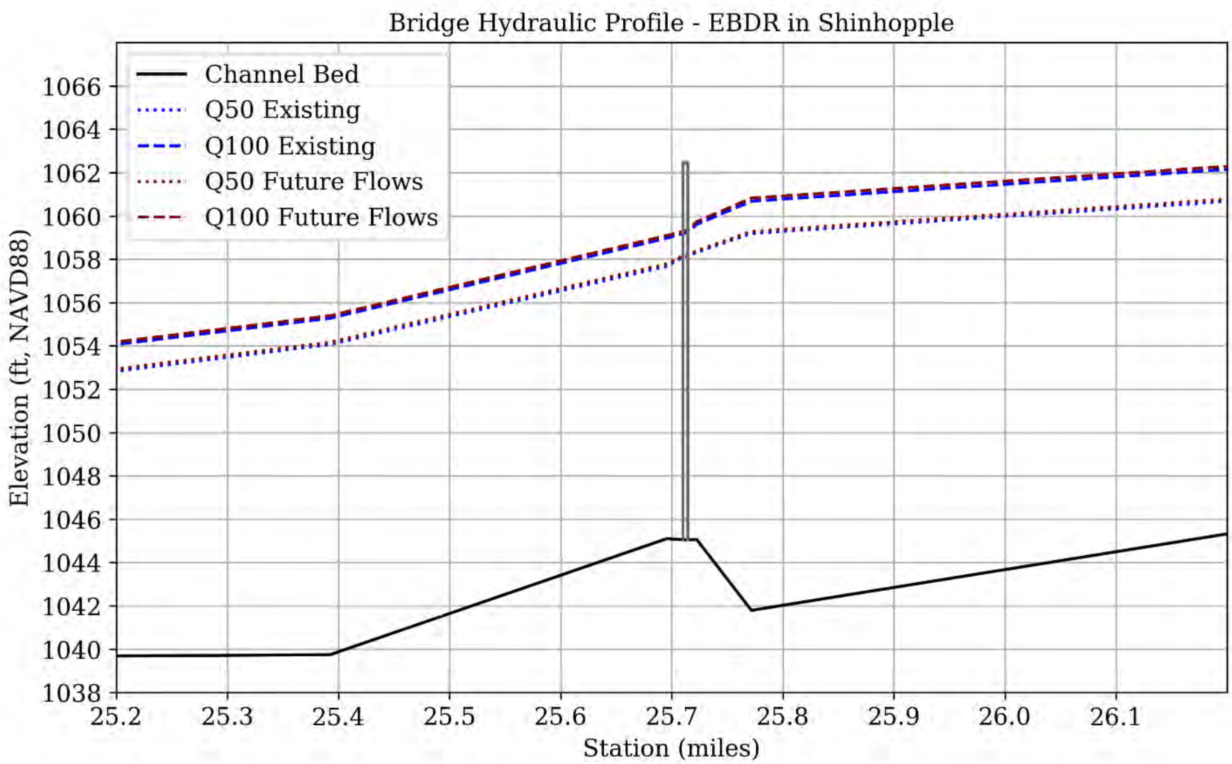


Figure 4-21: 50- and 100-year flood profiles at the River Road bridge across the EBDR in Shinhopple. Existing and projected future flow scenarios are plotted.

Shinhopple can be accessed by Route 30 and River Road in the EBDR valley or by Trout Brook Road, which follows the Trout Brook valley north toward Route 206 and Walton.

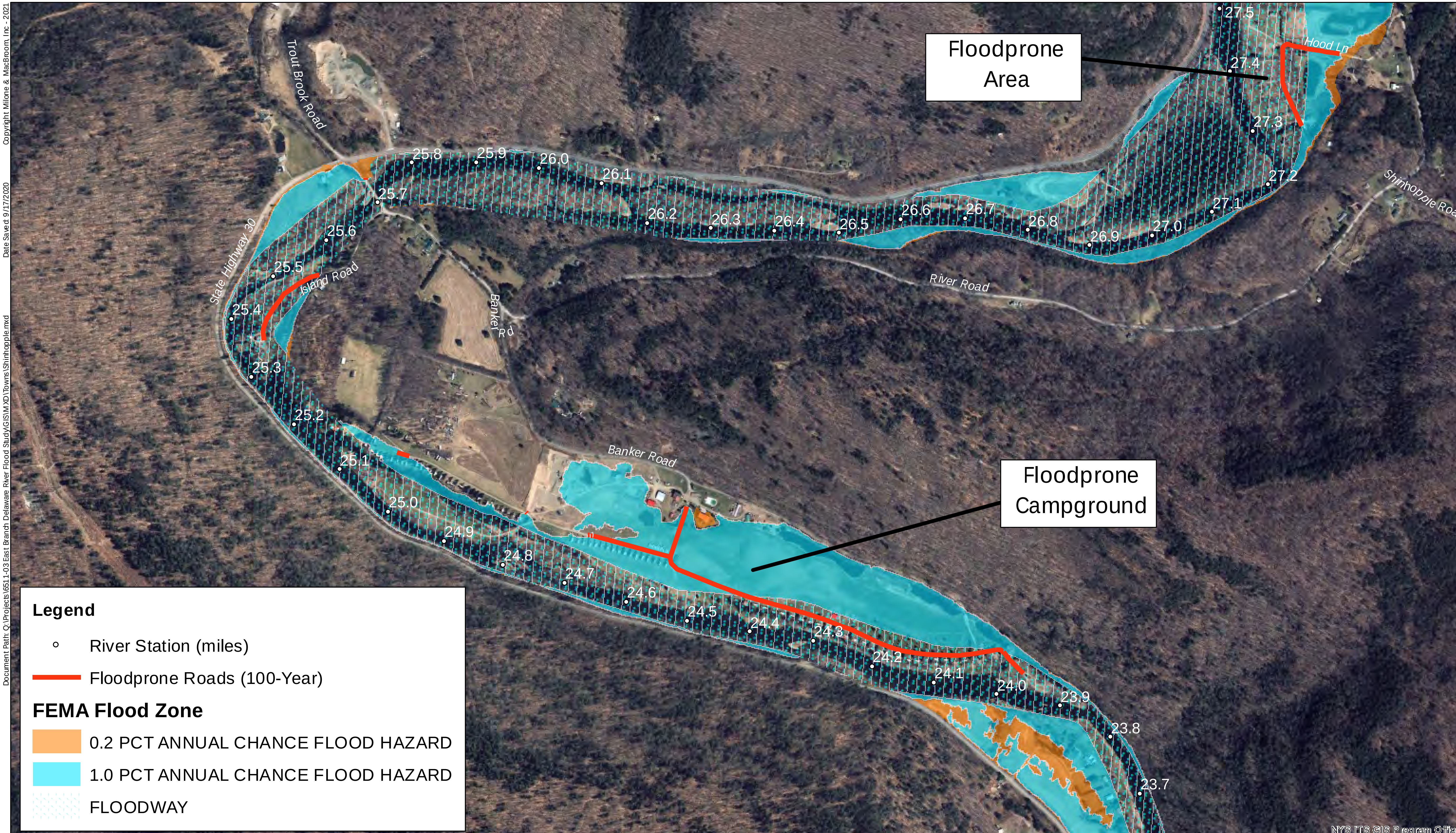
It is recommended that detailed hydraulic modeling be developed for Trout Brook in order to accurately assess the flood hazards in Shinhopple.

Flood-prone parcels have been identified through a GIS analysis as being within the 100- and 500-year floodplains, respectively, in the Shinhopple area. In summary, the GIS identified 66 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 4,352 acres (two parcels contain a total of 2,992 acres – the same two parcels as in the Harvard area; the boundaries of both analysis areas include these two parcels) within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional two parcels and 30 acres of land.

The 10-year floodplain in this area along the EBDR includes the floodway areas mostly on the bends of the river as well as the islands. Floodwater extends inland a significant distance around Hood Lane, the mouth of the Trout Brook, and the campground property across the river from Trout Brook.

The area subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly in some areas, and depths are increased. In Shinhopple, floodwaters reach the residential and commercial properties on the north and west sides of the river as well as much of the campground and the sand and gravel business on the south and east sides of the East Branch. The floodplain also covers part of Banker Road, the only access to the campground and sand and gravel business; however, it appears that double-track paths across the property would permit an emergency access. The floodplain inundates the cabin rental property but not the cabin itself.

Figure 4-23 is a relocation master plan for Shinhopple.



HIGH RISK AREA #6 - SHINHOPPLE (EBDR & TROUT BROOK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-22

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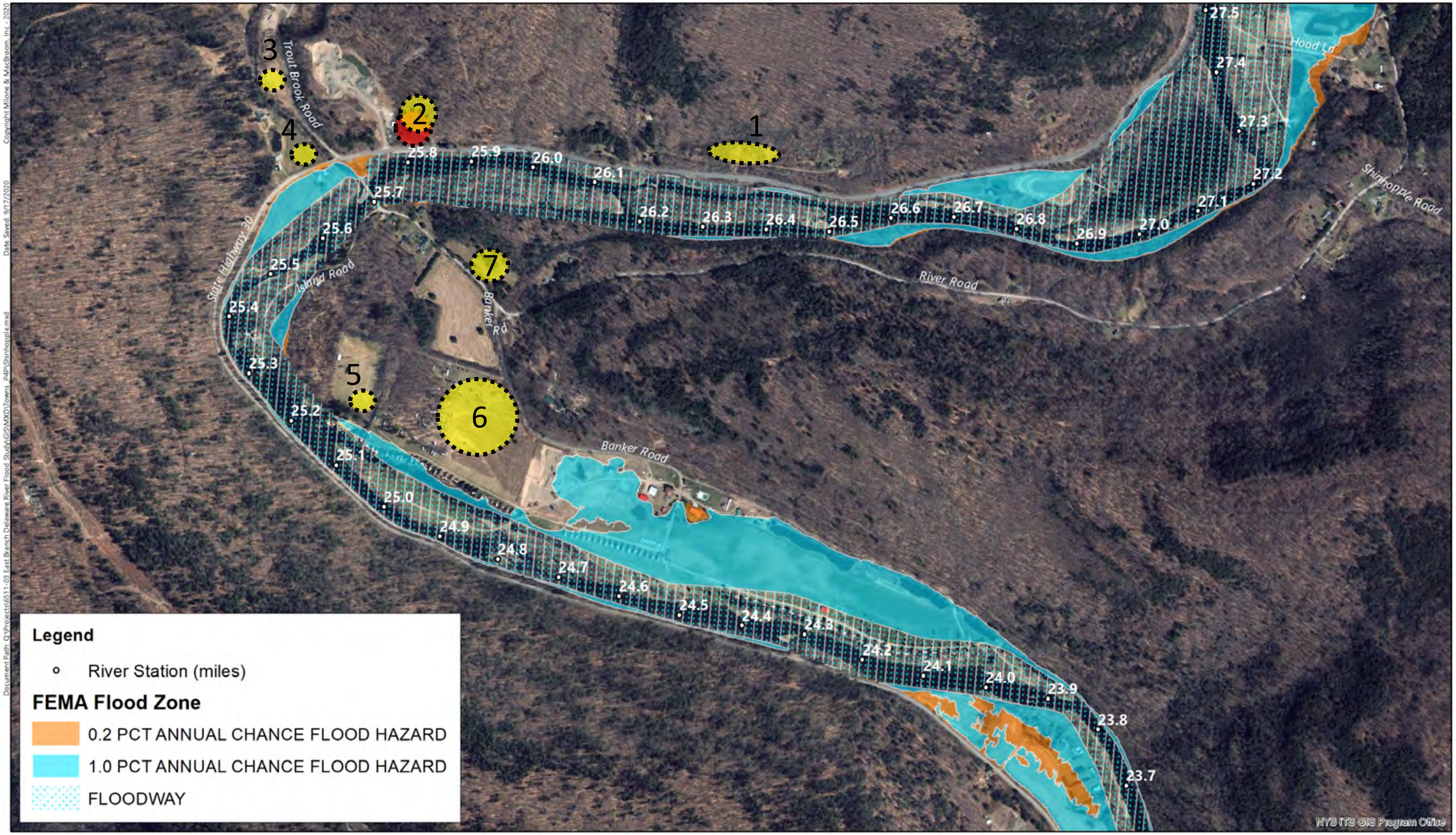
Shinhopple Conceptual Redevelopment Locations



HIGH RISK AREA #6 - SHINHOPPLE (EBDR & TROUT BROOK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-23

Potential Residential Relocation Area

Potential Non-Residential Relocation Area

0 150 300 600 900 1,200 1,500
Feet

1 in = 750 feet

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Shinhopple Conceptual Potential Redevelopment Locations

Vital Information

Existing conditions & likely scenarios for developing potential relocation areas:

1) 1 parcel consisting of ~31 Acres. Likely Density – Low (1-acre min. lot size). Development could utilize existing driveway location and several lots could be located along existing driveway alignment to minimize natural features impacts by utilizing the non-wooded areas on the parcel.

2) 1 parcel consisting of ~57 Acres. Likely Density – Low (1-acre min. lot size). If the quarry owner was willing to redesign their site, the existing driveway access could be utilized as shared driveway for all uses. Non-residential development may be possible in close proximity to the existing driveway connection to Route 30. Residential development would need to be separated from the existing quarry use, likely on the eastern side of the existing parcel, but given the size of the parcel and general landscape in the area there is adequate acreage to provide several home sites. Woodlands would need to be cleared (much of the site is heavily wooded) but selective clearing could potentially be undertaken.

3) 1 parcel consisting of ~3 Acres. Likely Density – Low (1-acre min. lot size). This lot could provide 2-3 parcels with minimal natural features impacts as the site is already cleared.

4) 1 parcel consisting of ~45 Acres. Likely Density – Low (1-acre min. lot size). 1-2 parcels could be provided as infill in the cleared portion of the site along Route 30.

5) 1 parcel consisting of ~5 Acres. Likely Density – Low (1-acre min. lot size). This is an existing homesite with two structures in the middle of the lot, however, 1-2 parcels may be feasible.

6) 1 parcel consisting of ~49 Acres. Likely Density – Low (1-acre min. lot size). The area proposed for a potential relocation is a small portion of the north end of the parcel. The area is used as storage and may also be farmed. There is an estimated potential of 10-15 parcels that could be provided.

7) 1 parcel consisting of ~26 Acres. Likely Density – Low (1-acre min. lot size). Development could be provided in the cleared area of approximately 3 acres fronting on River Road which would not require clearing of woodlands on the site.

4.9 High Risk Area #7 – Corbett

Corbett is a hamlet located on the EBDR in the town of Colchester, southeast of Downsville. Campbell Brook flows west through the hamlet and joins the EBDR immediately upstream of the Corbett Road suspension bridge. The Campbell Brook watershed covers 9.75 square miles to the south and east of the EBDR. The hamlet is accessible by Route 30 via the Corbett Road bridge and by River Road and Campbell Brook Road.

This small crossroads community consists of primarily residential uses and agricultural/ farming operations, although most of the community's original growth was associated with Corbett's acid factories. Most housing is constructed at the crossroads of Corbett Road and River Road; however, there are residences located along River Road and in close proximity, if not located along, NYS Route 30 just outside the crossroads area. Campbell Brook flows west through the hamlet and joins the EBDR immediately upstream of the Corbett Road suspension bridge.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Agriculture (100), Residential (200), Vacant Land (300), and Public Services (800).

These include the following:

- Residential
- Agriculture

Corbett is situated on the alluvial fan created by Campbell Brook, which has been channelized and straightened into an unnatural alignment within this depositional environment. Flooding can occur in Corbett when bridges and culverts are clogged with sediment and debris carried down Campbell Brook. This can cause substantial damage as the stream flanks these structures and flows across roadways and property.

Figure 4-25 is an aerial image of Corbett. Flood-prone areas including roads and critical facilities are labelled.

Corbett experienced flooding of Campbell Brook following a severe localized storm in 2012. Campbell Brook Road is frequently damaged by flooding of its namesake watercourse. Intermittent sidecast berms line the stream banks, and the remains of former mill dams and other man-made structures persist in the channel. This has left Campbell Brook in an impaired state that is susceptible to instabilities that are likely to cause damage to the adjacent roadway over time.

Photo 4-8
Corbett bridge during 2006 flood. Courtesy of Colchester Historical Society, Downsville, New York

According to the Delaware County All-Hazard Mitigation Plan, the Corbett Water Company is located within the EBDR floodplain.

Corbett Road crosses the EBDR on a fairly unique single-lane suspension bridge at STA 29.15 (BIN 3352060). The county-owned bridge was built in 1926 and has an 8-ton weight restriction. FEMA modeling indicates that this bridge does not appreciably influence flows in floods less than the 10-year event. In the more severe floods, the bridge deck does not overtop although the approach roadway is modeled as overtopping in the 500-year flood. This would severely limit access to Corbett as flooding on the EBDR sufficient to overtop the approach to Corbett Road bridge would also render River Road impassable; the only remaining access to Corbett is by Campbell Brook Road, itself likely to be heavily damaged in such a flood.

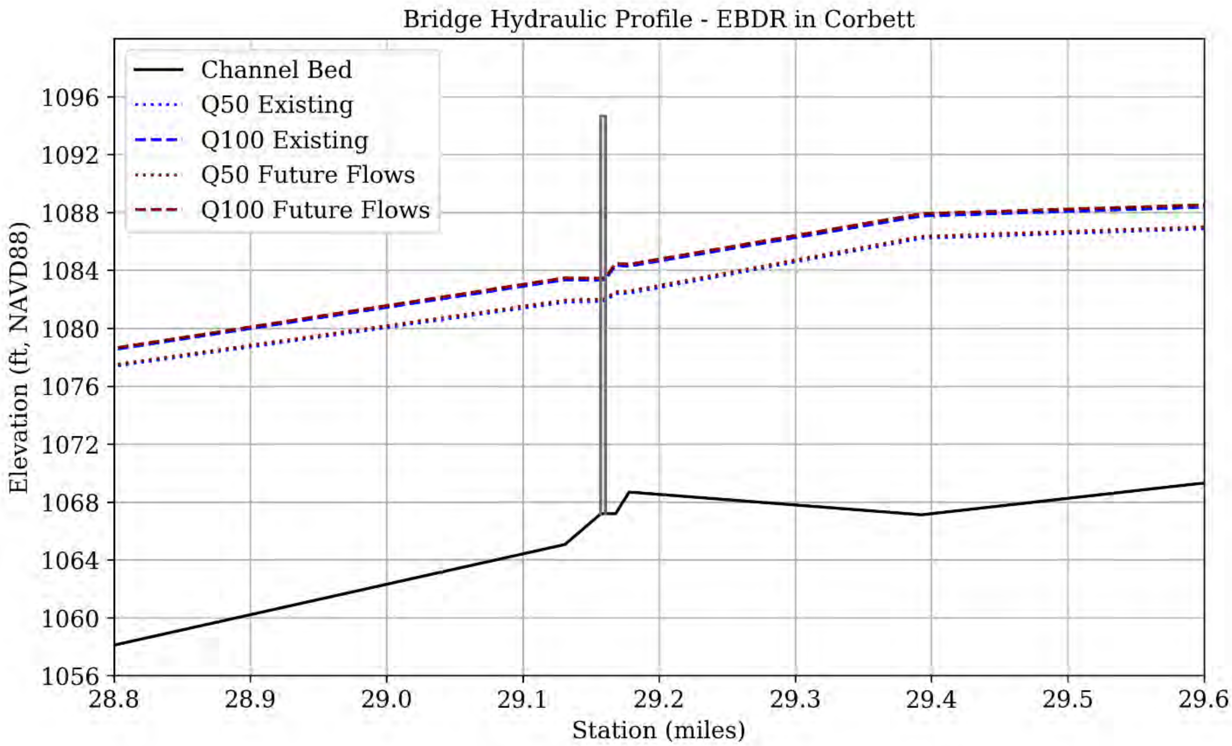


Figure 4-24: 50- and 100-year flood profiles at the Corbett Road suspension bridge across the EBDR in Corbett. Existing and projected future flow scenarios are plotted.

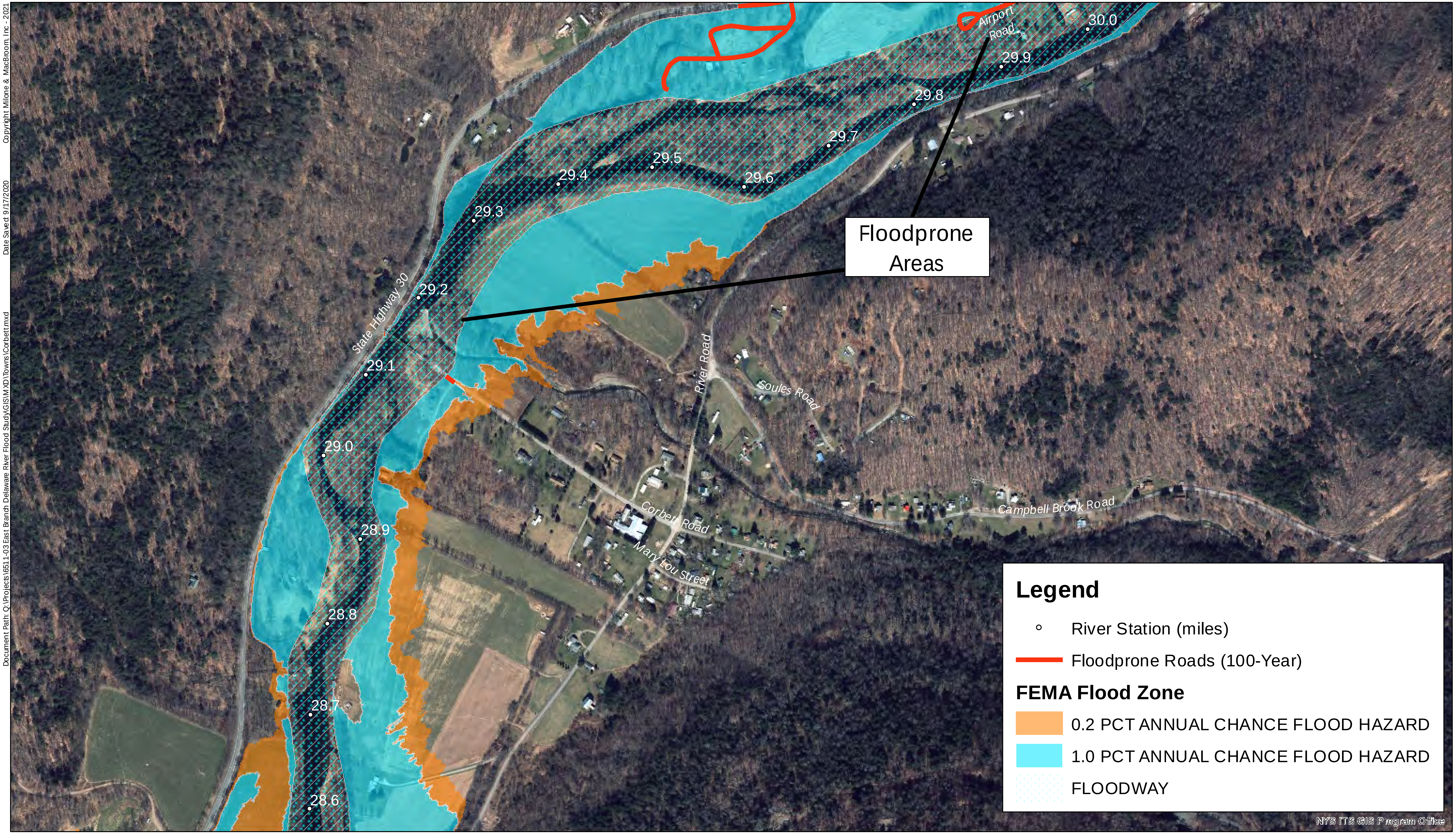
Campbell Brook is spanned several times by River Road, Campbell Brook Road, and Campbell Mountain Road. Additional bridges carry Hawk's Hollow Road and other local roads and private drives across Campbell Brook and its tributaries. Detailed hydraulic modeling would enable assessment of the flood hazards in Corbett.

Flood-prone parcels have been identified through a GIS analysis as being within the 100- and 500-year floodplains, respectively, in the Corbett area. In summary, the GIS identified 48 parcels with a total land area (not necessarily a flooded area – some parcels are only partially within a floodplain) of approximately 892 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional five parcels and 32 acres of land.

The 10-year floodplain in this area along the EBDR includes the floodway, islands, and the lowland areas primarily along the west side of the river. The floodplain inundates residential properties on the west side of the river.

The area subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly, primarily on the east side of the river, and depths are increased. Corbett is situated on the alluvial fan created by Campbell Brook, which has been channelized and straightened into an unnatural alignment within this depositional environment. Flooding can occur in Corbett when bridges and culverts are clogged with sediment and debris carried down Campbell Brook. This can cause substantial damage as the stream flanks these structures and flows across roadways and property.

Figure 4-26 is a relocation master plan for Corbett.



HIGH RISK AREA #7 - CORBETT (EBDR & CAMBELL BROOK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-25

0 100 200 400 600 800 1,000 Feet

1 in = 500 feet

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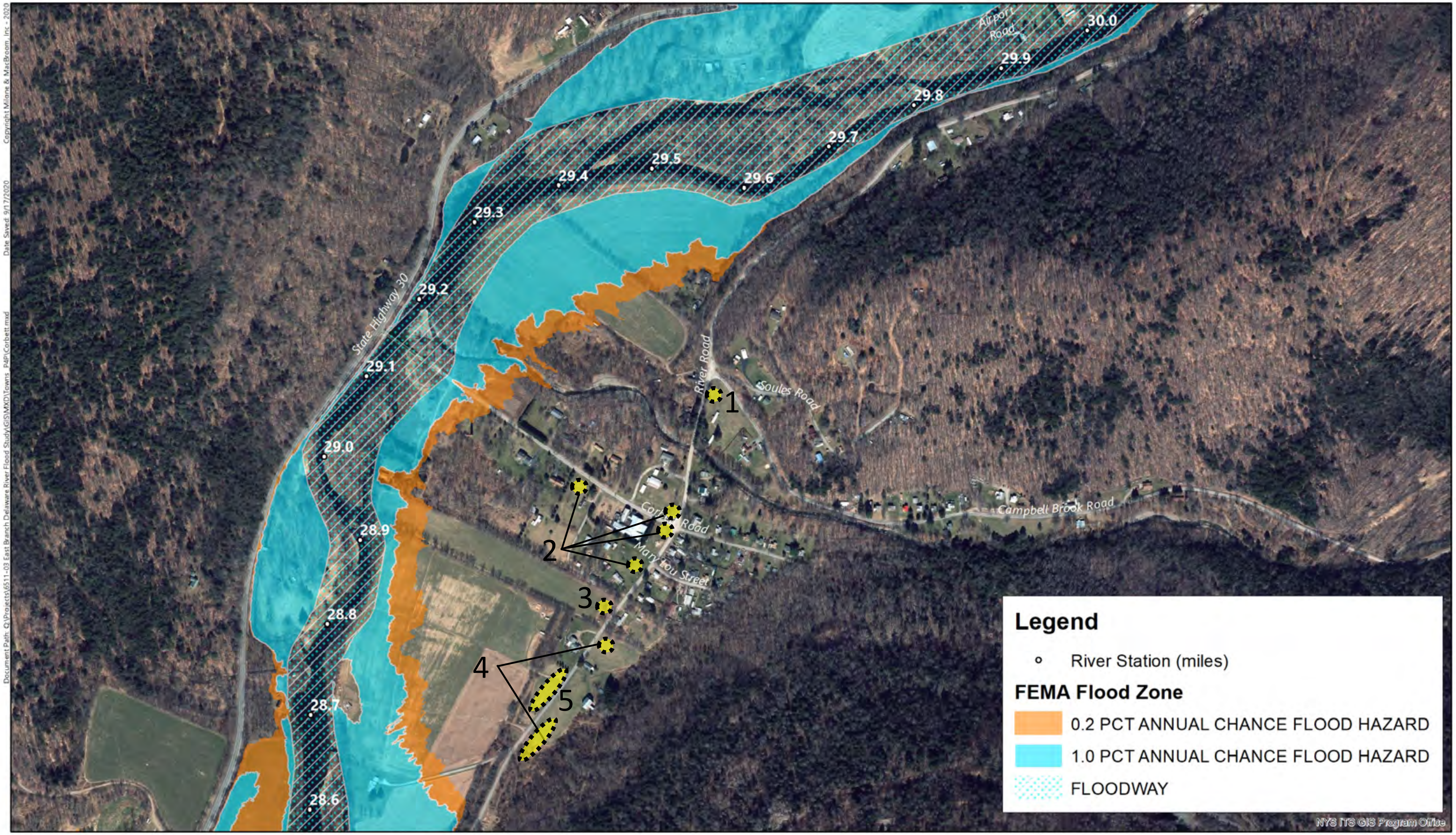
Corbett Conceptual Redevelopment Locations



HIGH RISK AREA #7 - CORBETT (EBDR & CAMBELL BROOK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-26

Potential Residential Relocation Area

Potential Non-Residential Relocation Area

0 100 200 400 600 800 1,000
Feet

1 in = 500 feet

N

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Corbett Conceptual Potential Redevelopment Locations

Vital Information

Existing conditions & likely scenarios for developing potential relocation areas:

1) 1 parcel consisting of ~4 Acres. Likely Density – Low (1-acre min. lot size). This potential infill lot has an existing home but could be subdivided into 1-2 additional lots.

2) 4 parcels consisting of <5 Acres. Likely Density – Medium/Low (1/4-acre to 1-acre min. lot size). There is the potential for 3-4 infill parcels to be considered. All but one lot has an existing structure.

3) 1 parcel consisting of ~7 Acres, Likely Density – Medium (1/2-acre min. lot size). This is a narrow and deep parcel that has the potential for 1-2 (possibly more) parcels if a flag-lot and shared driveway approach were feasible.

4) 1 parcel consisting of ~109 Acres. Likely Density – Low (1-acre min. lot size). This parcel has the potential for several lots located along River Road where the land, in some cases, is generally cleared. Interior areas of the site are heavily wooded.

5) 2 parcels consisting of ~23 Acres. Likely Density – Low (1-acre min. lot size). Both lots appear to be actively farmed, however, there is land along River Road that could provide adequate acreage to provide 2-3 parcels without significantly impacting the existing agricultural operation.

4.10 High Risk Area #8 – Downsville

Downsville is a hamlet located in the town of Colchester and is one of the larger, denser areas located along the East Branch. The core area – Bridge Street/Route 30/Route 206 and Knox Avenue is a mix of commercial, residential, institutional, recreation, and vacant land. Of the communities on the EBDR, Downsville benefits most from the flood attenuation provided by the Pepacton Reservoir since its construction, which is purely a function of proximity. However, the hamlet has historically experienced relatively frequent flooding from the EBDR, Downs Brook, and Wilson Hollow Brook.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Residential (200), Vacant Land (300), Commercial (400), Recreation and Entertainment (500), and Community Services (600).

These include the following:

- Residences
- Commercial properties
- The Town of Colchester Pool and Downsville Fire Department baseball fields
- The Downsville Central School property
- The Town Highway property and cemetery

Photo 4-9
Flooding in Downsville, 1895. Covered bridge at top left of photograph. Courtesy of Colchester Historical Society, Downsville, New York

Figure 4-28 is an aerial image of Downsville showing flood-prone areas, roads, and critical facilities.

FEMA modeling indicates that the Route 30/206 bridge spanning the EBDR at STA 33.1 is flanked and overtops in the estimated 50-year flood (BIN 1020790). However, this structure was replaced in 2017, and the new bridge is not represented in the model; hydraulic analysis performed for the NYSDOT shows that the maximum backwater elevation is reduced by 0.05' with the new bridge in both the design and basic discharges, or 50- and 100-year floods, respectively. Flooding depths or extents are likely not appreciably changed as a result of this bridge replacement.

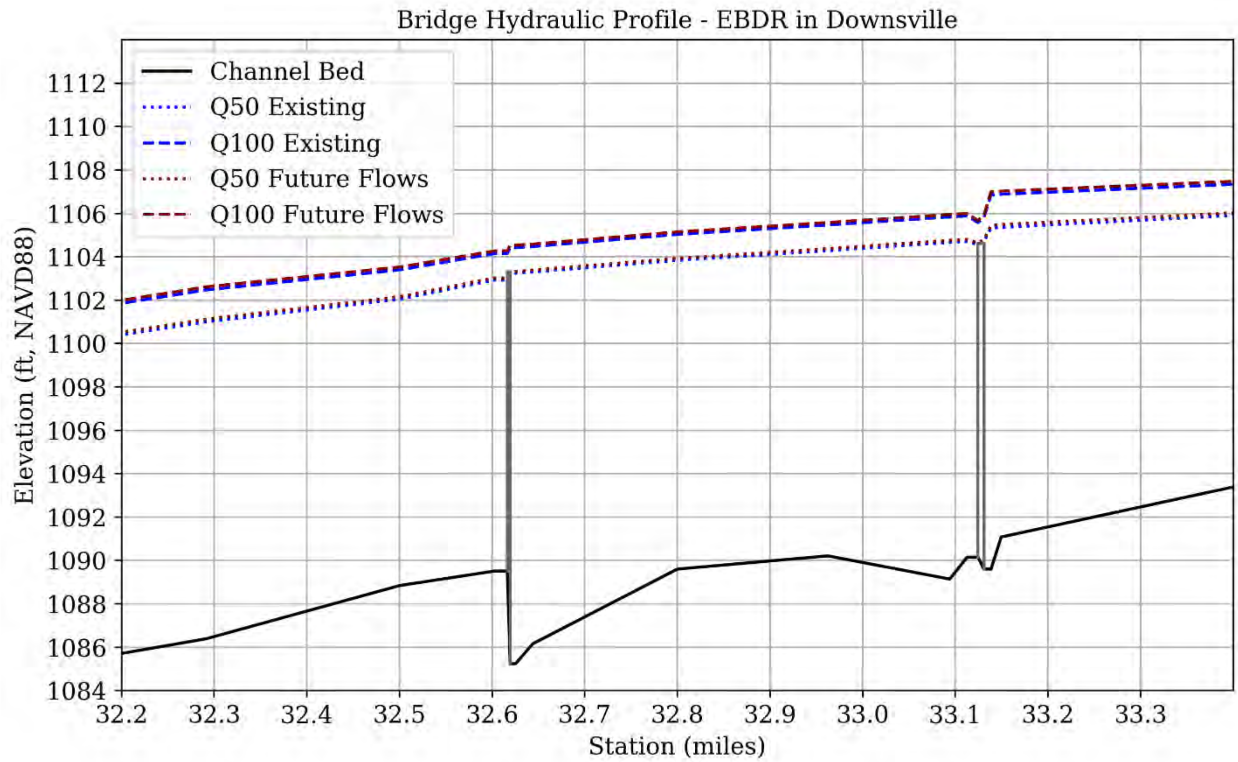


Figure 4-27: 50- and 100-year flood profiles at the Downsville Covered Bridge (left) and Route 30 (right) bridges across the EBDR in Downsville. The new (2017) Route 30 bridge is not reflected in FEMA modeling although NYSDOT hydraulic analysis of the new structure indicates that flooding is not appreciably affected. Existing and projected future flow scenarios are plotted.

The approach roadway to the historic Downsville Covered Bridge, at STA 32.6 on the EBDR, is modeled as being overtopped in the 10-year flood and greater, with the bridge having just 0.1 feet of freeboard in the 50-year flood. Flood elevations at the covered bridge may be slightly affected by the new Routes 30/206 bridge. This nationally registered historic structure was originally constructed in 1854 and features an impressive 174-foot single span; the bridge has been restored in recent decades and currently has a 3-ton weight restriction (BIN 3352070).

The Route 30 crossing of Downs Brook is included in effective FEMA modeling from 1985, which extends roughly 4,300 feet upstream from the confluence with the EBDR.

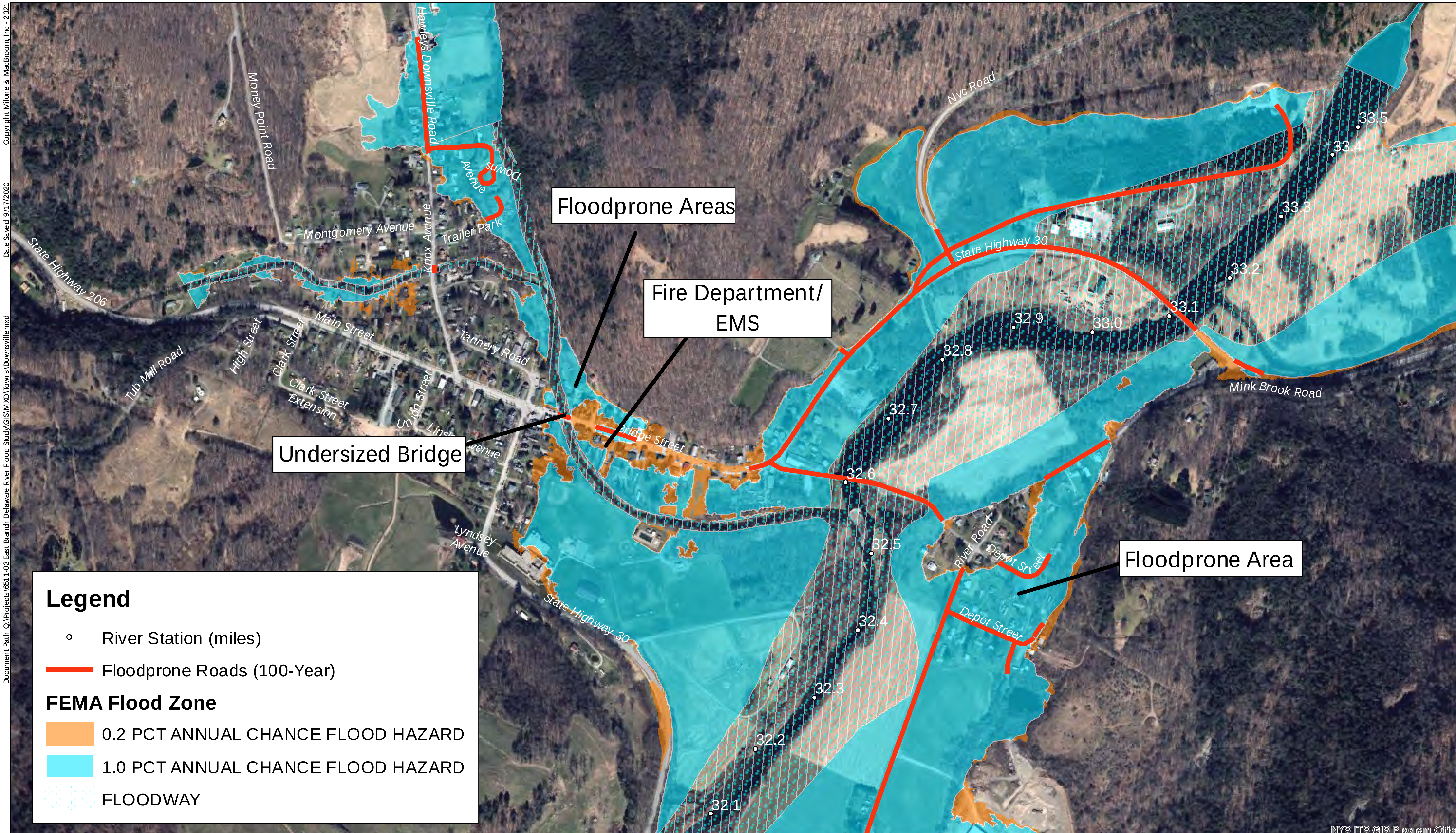
Flood-prone parcels in Downsville have been identified through a GIS analysis as being within the 100- and 500-year floodplains. In summary, the GIS identified 171 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 7,734 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional 21 parcels and 158 acres of land. Flood-prone critical facilities were identified: the Downsville Volunteer Fire Department and Emergency Medical Services building is mapped as partially within the SFHA and wholly within the 500-year floodplain; the NYCDEP building complex is located in the SFHA as well as the regulatory floodway; the Downsville Water Supply Facility is located within the SFHA.

The 10-year floodplain in this area along the EBDR includes the floodway and the lowland areas along the bend in the river, agricultural land on both sides of the river west (downriver) of the Downs Brook, along the Downs Brook in the northern end of Downsville, and amongst the mixed-use area along Route 206, running adjacent to Downs Brook.

The area subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly in the northeast area and on the northern side of the river, south of the mouth of Downs Brook. Depths for the 100-year floodplain are increased. Much of the core area and surrounding area noted above (the area south of where Route 30 and Route 206 intersect), as well as the area along Downs Brook headed north of this intersection, is within the area subjected to floodwaters during a 100-year flood. The area subjected to floodwaters during a 100-year flood includes much of the grade school property and all of the Town Pool property and the Fire Department ball fields as well as most of the land south of Route 30 in this area. Downs Brook flows west through the hamlet and joins the EBDR approximately a mile downstream of the Pepacton Reservoir. Downs Brook drains just over 27 square miles; the 372-square-mile watershed of the EBDR upstream of Downsville is regulated by the Pepacton Dam.

Photo 4-10
Flood damage in Downsville, 1942. Courtesy of Colchester Historical Society, Downsville, New York

Downs Brook is highly entrenched as it flows between the Routes 30/206 bridge and the EBDR. The stream has hard-armored banks along this reach, and high velocities develop. Farther upstream, Downs Brook is entrenched against the southern valley wall but is somewhat more connected to its floodplain, leading to flooding in adjacent neighborhoods. When floodwaters overtop the left bank just upstream of the Routes 30/206 bridge, damaging flows run down the road and through the village.



HIGH RISK AREA #8 - DOWNSVILLE (EBDR & DOWNS BROOK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-28

0 100 200 400 600 800 1,000
Feet
1 in = 600 feet

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Floodplain Benching along Downs Brook

An HEC-RAS two-dimensional unsteady-state hydraulic model was developed for approximately 5,000 linear feet of Downs Brook and roughly 2.5 miles on the EBDR. A series of flood event scenarios were evaluated, including coincident peak flows on the EBDR and Downs Brook. The flood stage on the EBDR significantly influences the hydraulics on Downs Brook by causing a backwater affect from the confluence extending as far as 1,000 feet up Downs Brook during coinciding 100-year peak flows, decreasing for lower magnitude events. For the purpose of investigating flood mitigation scenarios on Downs Brook, it was assumed that flow on the EBDR would be limited to the 740 cfs release amount at the Pepacton Reservoir dam, which would be more likely to take place than the coincident peaks.

Photo 4-11
Routes 30/206 bridge over Downs Brook, Downsville

Two-dimensional hydraulic modeling of Downsville shows that the Route 30/206 bridge over Downs Brook is a moderate constriction to flows and contributes to increased backwater flooding depths. Floodwaters that overtop the stream banks as a result flow through the downtown area. Removal of the bridge structure from the model produced reductions in water surface elevations for all modeled peak discharges and ranged from 0.5 to 1.5 feet. However, the hydraulic model indicated that increasing the size of the bridge to accommodate larger flows would not prevent floodwaters from breaking over the left bank upstream of the bridge as frequent as the 10-year storm. Various floodplain bench alternatives were modeled to discourage floodwaters from leaving the stream channel. Figure 4-29 shows the proposed conditions layout that was modeled, which would reduce overall disturbance and mitigate flood damage.

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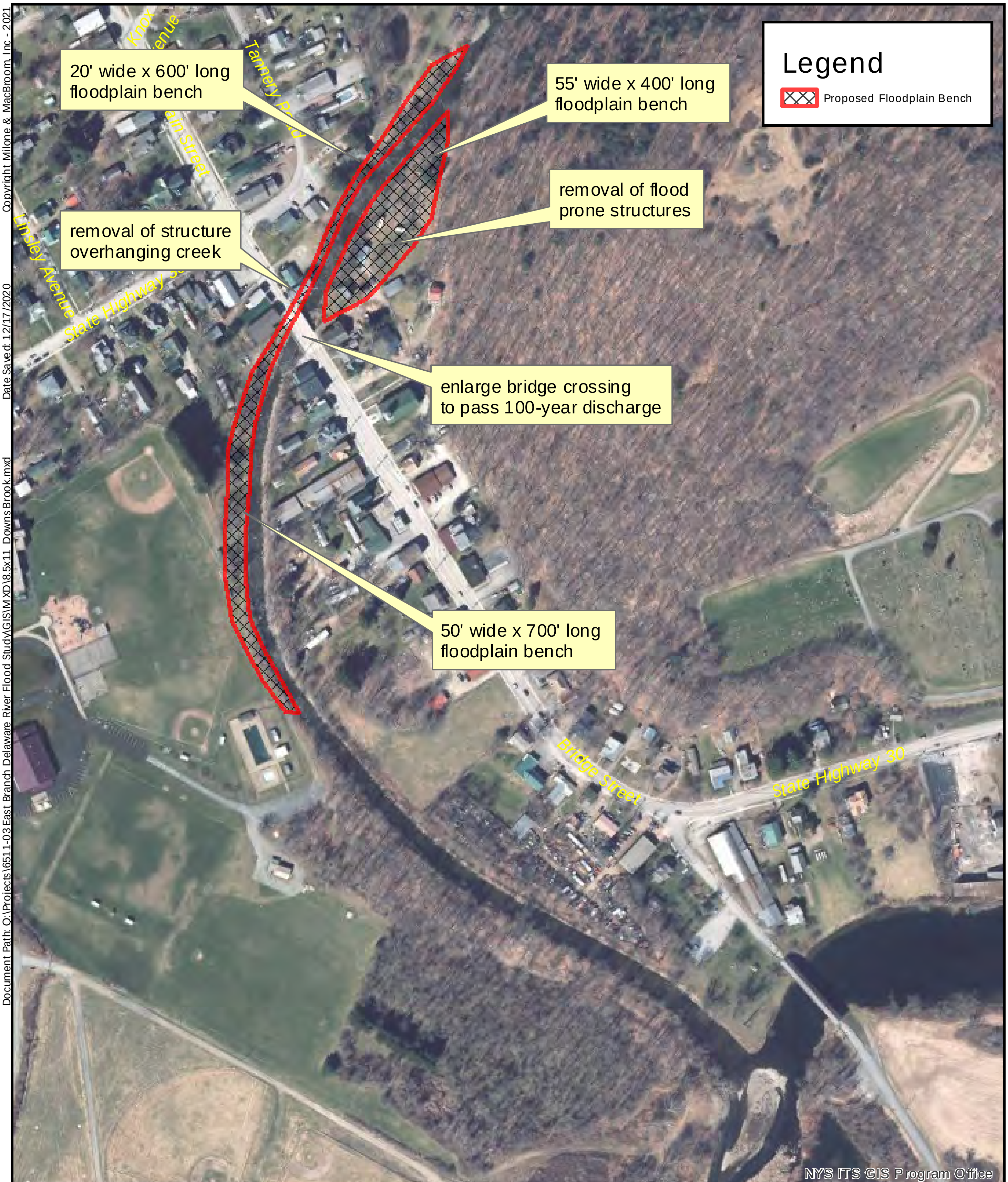

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DOWNS BROOK FLOOD MITIGATION ANALYSIS

EAST BRANCH DELAWARE RIVER
FLOOD RESILIENCY STUDY

DELAWARE COUNTY
NEW YORK

0 400 Feet

SCALE	1 " = 300 '
DATE	1/13/2021
PROJ. NO.	7160-01

FIG. 4-29

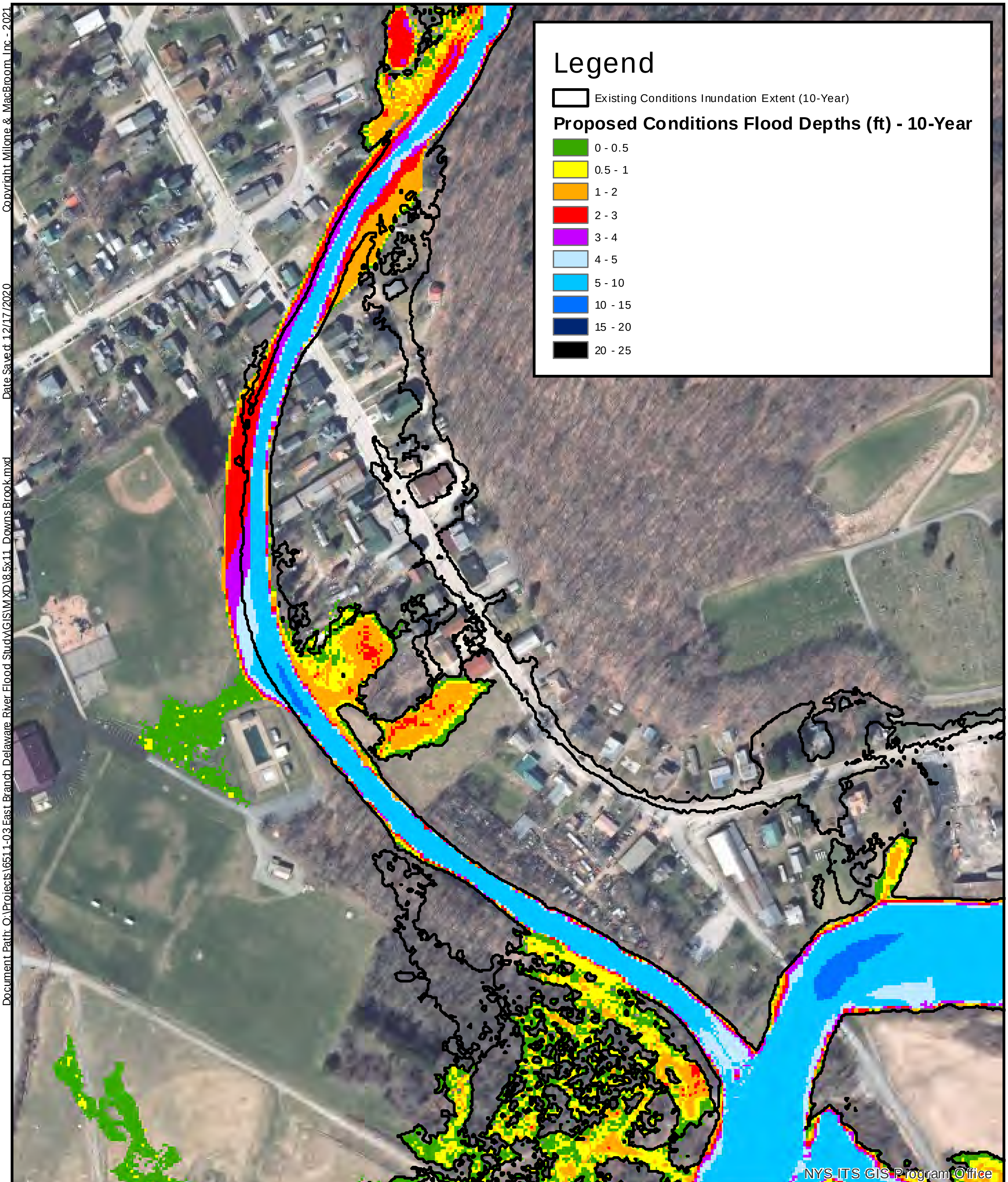
The floodplain benching was evaluated under all modeled peak flows on Downs Brook, with the Pepacton Reservoir release discharge on the EBDR. Water surface elevations under existing and proposed conditions were evaluated at the upstream and downstream ends of the floodplain, near the locations where reductions begin to diminish and tie back into existing flood depths. Table 4-5 summarizes the magnitude of water surface elevation reductions from the proposed floodplain bench.

TABLE 4-5
Water Surface Elevation Reductions from Proposed Floodplain Benching along Downs Brook (Measurements Taken at the Bench Upstream and Downstream Terminus)

Flood Return Interval (years)	WSE Reductions (Upstream / Downstream)
10-Year	1.60 ft / 0.74 ft
25-Year	1.97 ft / 0.70 ft
50-Year	2.06 ft / 0.63 ft
100-Year	1.97 ft / 0.58 ft

WSE = water surface elevation

The following set of Figures (4-30 through 4-33) illustrates proposed conditions depth grid mapping superimposed with the existing conditions inundation extents for the 10-, 25-, 50-, and 100-year events. The model outcome suggests that the proposed floodplain benching, in conjunction with an adequately sized Route 30 bridge, would reduce flooding at homes and businesses that are situated along the southern portion of main street. The model configuration would prevent floodwaters from exiting the left bank upstream of the bridge as early as the 10-year discharge. Flood reduction benefits were also seen during the modeled 100-year peak discharge by lowering headwater depths upstream of the bridge and disallowing floodwaters from pouring over the left bank and causing widespread flooding along Main Street. As illustrated in Figure 4-33, the proposed floodplain bench layout has the potential to remove a series of homes and businesses from the 100-year floodplain, including critical infrastructure such as the Downsville Fire Department building. Given the underlying benefits of implementing a flood mitigation alternative as modeled, it is in the community's best interest to consider further investigating alternative floodplain layouts in order to arrive at a solution that is cost effective and that meets the community's needs.



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DOWNS BROOK FLOOD MITIGATION ANALYSIS

EAST BRANCH DELAWARE RIVER
FLOOD RESILIENCY STUDY

DELAWARE COUNTY
NEW YORK

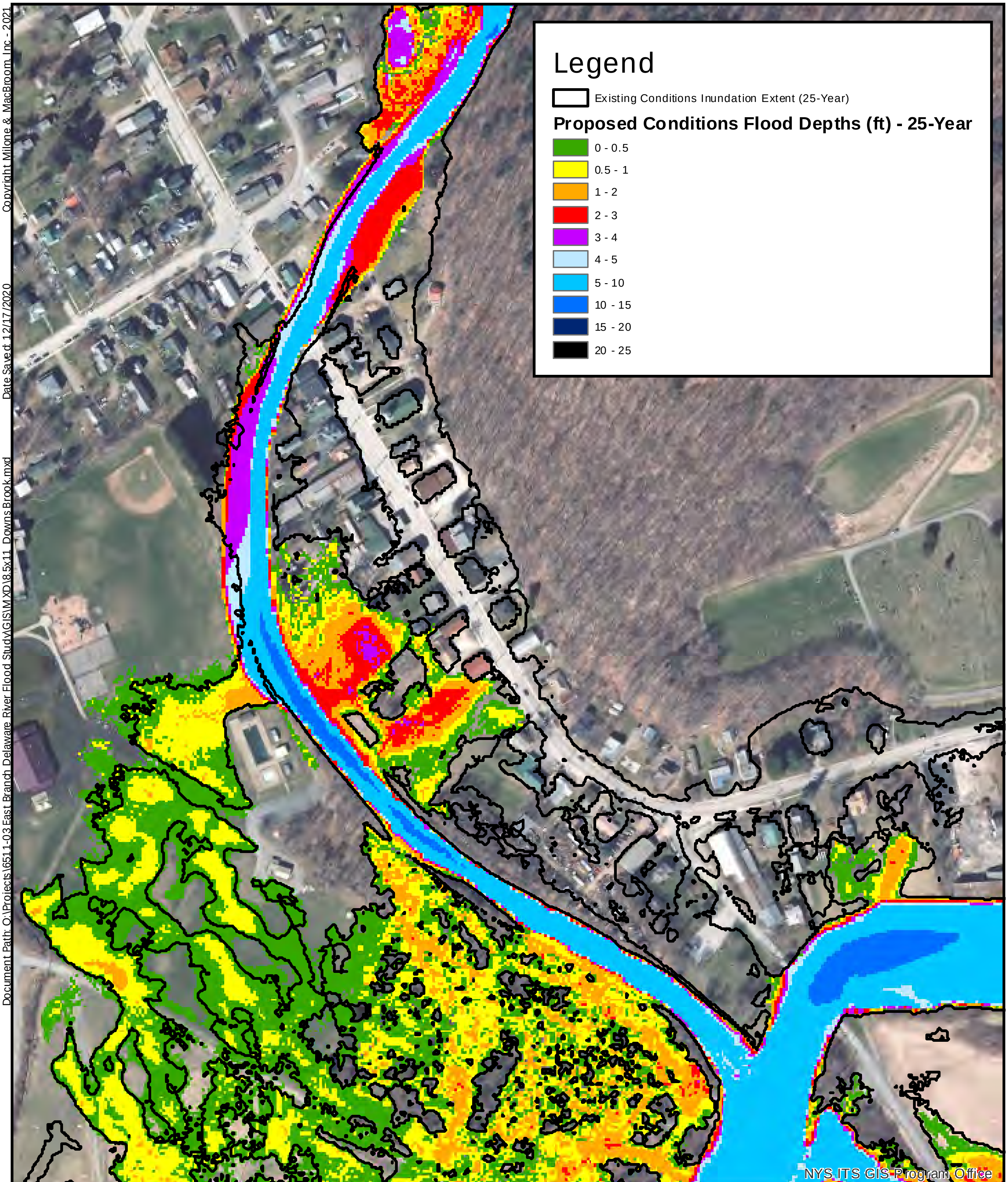
0 400
Feet

SCALE 1" = 300'

DATE 1/13/2021

7160-01
PROJ. NO.

FIG. 4-30



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DOWNS BROOK FLOOD MITIGATION ANALYSIS

EAST BRANCH DELAWARE RIVER
FLOOD RESILIENCY STUDY

DELAWARE COUNTY
NEW YORK

0 — 400 Feet

SCALE	1 " = 300 '
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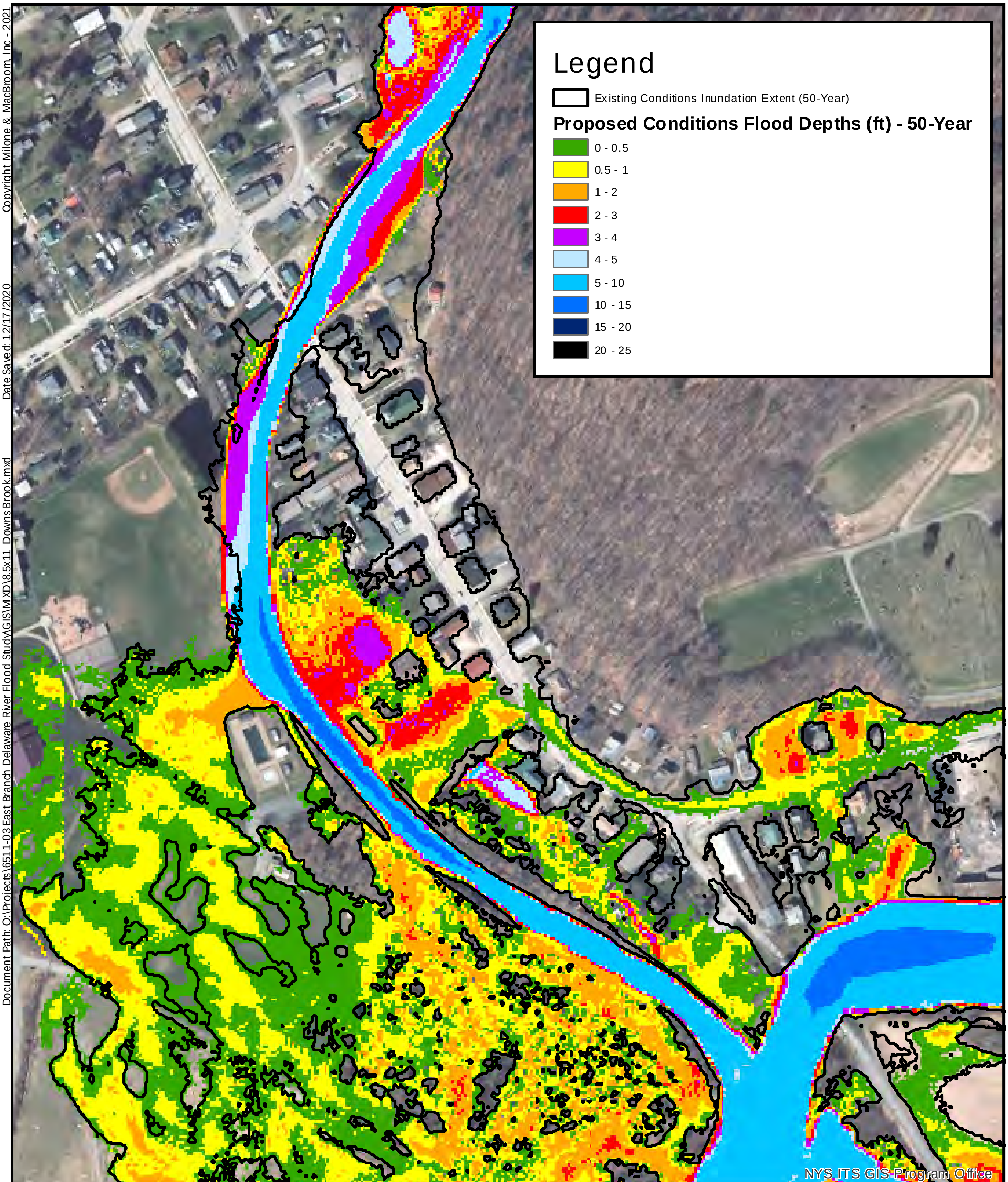
FIG. 4-31



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DOWNS BROOK FLOOD MITIGATION ANALYSIS

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FLOOD RESILIENCY STUDY

DELAWARE COUNTY
NEW YORK

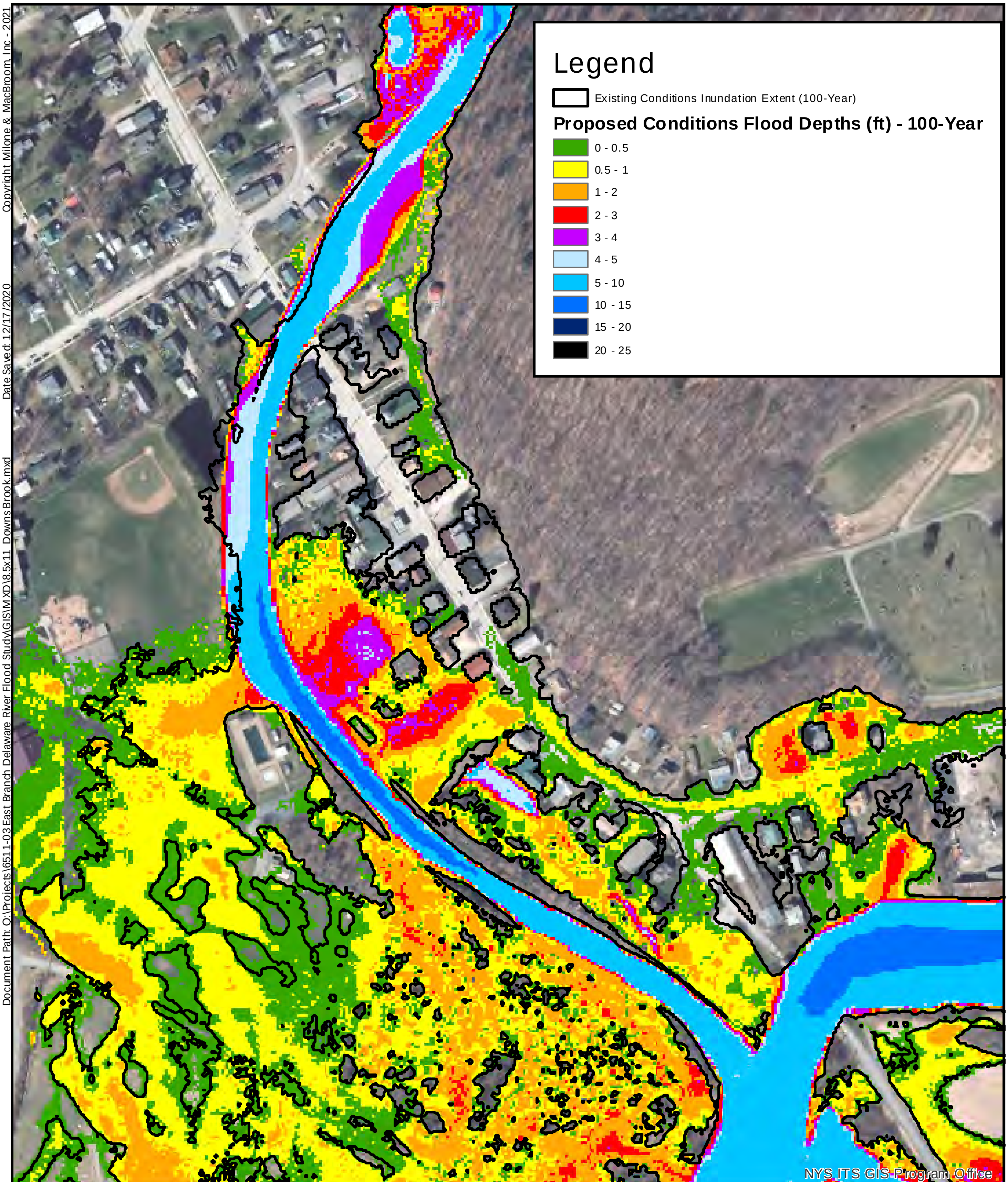
0 400
Feet

SCALE 1 " = 300 '

DATE 1/13/2021

7160-01
PROJ. NO.

FIG. 4-32



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EAST BRANCH DELAWARE RIVER
FLOOD RESILIENCY STUDY

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NEW YORK

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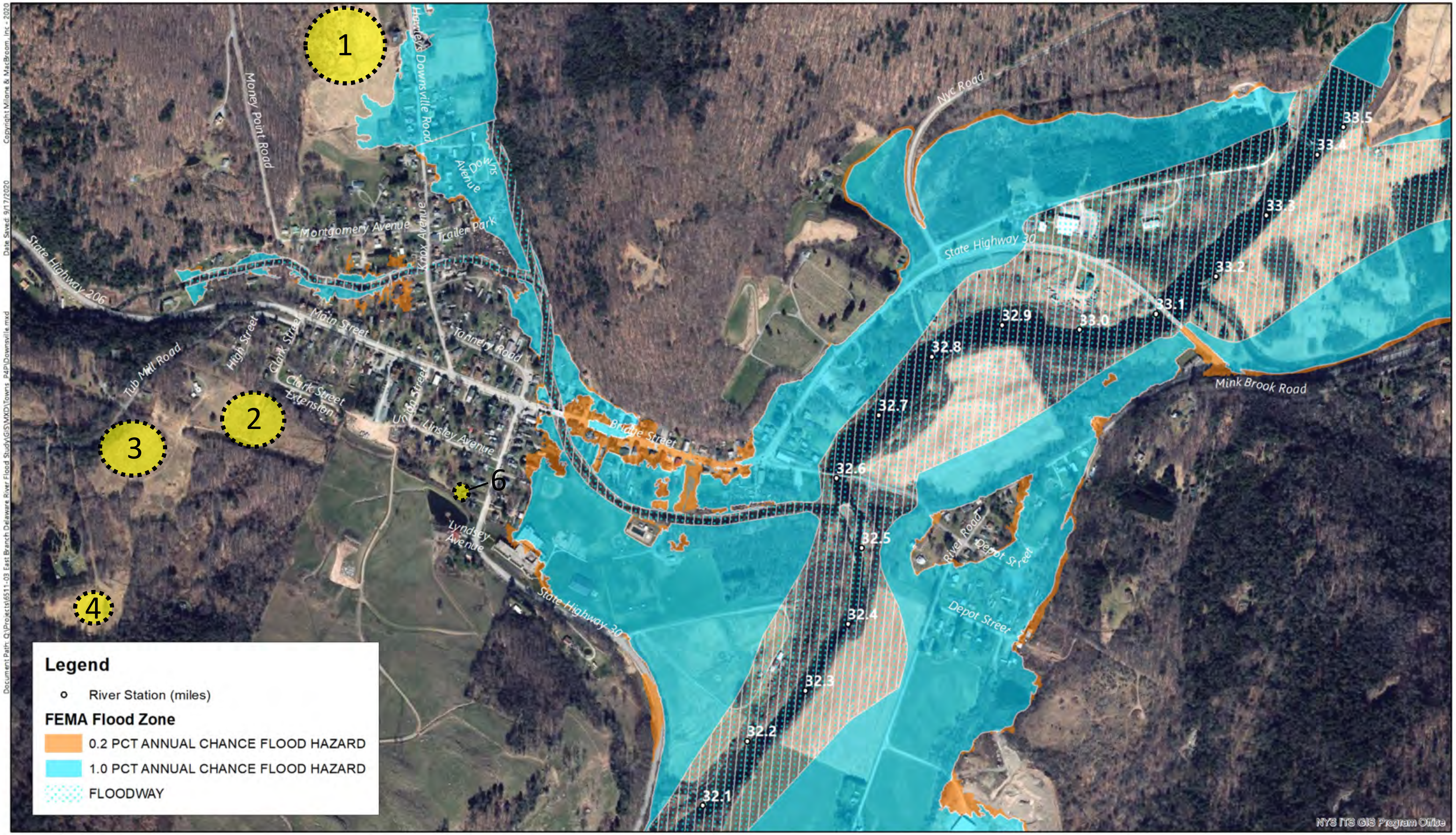
FIG. 4-33

Downsville Conceptual Redevelopment Locations



HIGH RISK AREA #8 - DOWNSVILLE (EBDR & DOWNS BROOK)

EAST BRANCH DELAWARE RIVER FLOOD STUDY - SD060

FIGURE 4-34

Potential Residential Relocation Area

Potential Non-Residential Relocation Area

0 100 200 400 600 800 1,000 Feet

1 in = 600 feet

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Downsville Conceptual Potential Redevelopment Locations

Vital Information

Existing conditions & likely scenarios for developing potential relocation areas:

1) 1 parcel consisting of ~111 Acres. Likely Density – Low (1-acre min. lot size). The site appears to be former farmland (does not appear to be actively farmed) and woodland. Parcels could be placed in the woodland area with practices to minimize tree removal and siting should be out of the floodplain which does cover some of the parcel/area.

2) 1 parcel consisting of ~8 Acres. Likely Density – Medium (1/2-acre min. lot size). This undeveloped lot appears to be mostly cleared with low brush on-site. A new road or shared driveway would be required to provide for several lots in this location.

3) 2 parcels consisting of ~20 Acres. Likely Density – Medium to Low (1/2-acre to 1-acre min. lot size). Several lots could be developed on this mostly cleared site with access to Tub Mill Road.

4) 1 parcel consisting of ~50 Acres. Likely Density – Medium/ to Low (1/2-acre to 1-acre min. lot size). A cleared area at the northeastern corner of the lot with what appears to be an existing dirt drive could provide for 2-3 parcels without needing to clear the dense woodlands.

5.0 RECOMMENDATIONS

At varying degrees of intensity over the past few centuries, the EBDR and its tributaries have experienced dredging, berming, straightening, channelization, damming, and relocation to one or the other valley wall. Historically, these efforts were often targeted at flood control, maximizing agricultural land, minimizing bridge crossings, powering grist and sawmills, and maintaining clear channels for log drives. Current flood mitigation and stream restoration efforts are frequently constrained by the development that grew along these heavily modified waterways; communities sprung up around the timber, bluestone, railroad, agriculture, and mill industries that concentrated along the most extensively altered rivers and streams. Today, the communities remain, but without many of the industries that had spurred their growth along the riverbanks. Our understanding of river morphology and flood dynamics have advanced significantly since the days of tributary mill dams, acid factories, and log drives on the EBDR, and these villages and hamlets now find themselves caught in the middle. It is difficult to understate just how significantly these streams have been modified over the years, so unfortunately, in many cases, it is difficult to design meaningful flood mitigation projects without altering the affected communities.

It is common for historical channel modification practices to instigate long-term instability issues that can exacerbate the flooding damages that are experienced today. For this reason, regulatory agencies rarely allow these activities without extensive review, and permitted debris clearing and public funding availability is generally limited to flood recovery efforts. These practices simply maintain a stream's impaired state without addressing the source of the impairment, which is why some of the most effective flood mitigation projects are also river restorations. By accommodating the streams' natural tendencies, flooding damages and property loss can be substantially alleviated. However, it is difficult for restoration and flood mitigation projects to establish stable conditions that reduce flood hazards without providing space for some degree of natural floodplain functions or alluvial fan processes to occur. In developed areas, this may require reclamation of property, removal of berms, or relocation of flood-prone homes, businesses, infrastructure, or critical facilities.

Where practical, tributary stream restoration projects should be associated with adjacent infrastructure improvements. This will help avoid repetitive losses. In the EBDR basin, the roadways that follow tributary valleys are critical detour routes, but themselves can be highly susceptible to flooding damage. A holistic approach to improving infrastructure resiliency can include a combination of stream rehabilitations, bridge and culvert upgrades, roadway relocations, drainage improvements, asset consolidation, and, in some cases, strategic disinvestment.

5.1 Relocations

In Section 4.0 of this report, Flood Mitigation Analysis, the analysis and discussion for each flood-prone community along the EBDR includes a relocation master plan. The relocation plans are intended to be used on a voluntary basis by county planners, municipalities, and individual property owners to guide potential relocation out of and away from flood-prone areas. They are intended to be flexible and may be implemented by one property owner, or by several, or by a residential neighborhood or business district. The plans are intended to provide options for relocations to occur within a community.

Recommendation:

- Implement voluntary relocation of flood-prone homes and businesses out of areas that are prone to flooding. (Relocation Mater Plans are provided in Section 4.0 for each flood-prone community.)

5.2 Channel Restoration and Floodplain Enhancement

Channel restorations in developed areas often involve what is called floodplain benching, or creation of a multistage channel. This is a process wherein adjacent land on one or both sides of the stream channel is excavated to a specified depth to provide additional flow conveyance in flood events. The normal, or low-flow, channel can be sized to accommodate a range of considerations, including sediment transport equilibrium and aquatic organism habitat. The floodplain bench elevation is set to a specific flood flow, which could be anywhere from fairly frequent, even annual, to a relatively rare, 5- or 10-year event. This will depend on the goals and constraints of individual projects. In some cases, two or more tiers or stages of benches can be designed to address more unique situations with multiple or conflicting objectives.

When flows spill onto these benches, the river's energy dissipates across the floodplain, reducing erosive forces in the channel. As floodwaters rise, the combination of the channel plus floodplain bench effectively acts as one, much larger, channel. These generally require minimal maintenance and can be designed to convey some of the most severe floods, but only as long as enough space is available alongside the river. In some cases, this may only affect fields, forests, or maybe backyards and parking lots, but in more built-up areas, removal or relocation of buildings and infrastructure may be necessary. These topics can be very complex and difficult for property owners, businesses, and communities as a whole, and must be considered individually and objectively. In some of the smaller tributary communities, these decisions may approach the existential; after the performing relocations necessary for a flood mitigation project, there would be nothing left to save from flooding.

One of the important dynamics in the EBDR basin is the prodigious volume of sediment that is delivered to the valley floor by the river's tributaries, which must be considered in restoration design in this watershed. While this is a natural process, many of these tributaries are heavily incised due to encroaching development and infrastructure, both historical and modern. This impaired state has fostered headcutting and bank failures that contribute massive quantities of sediment to the stream. As previously discussed, much of this sediment is deposited once the stream's energy diminishes; this can fill entrenched channels that run through communities, clog bridges and culverts, and cause channel avulsions. The preferred course of action is to address the source of the surplus sediment proactively. Recommendations include stabilizing active bank failures and setting grade controls to inhibit headcutting as part of stream restoration projects on these tributaries. There is an emergent need for up-to-date hydraulic modeling on these streams to assess both the existing flood hazard as well as mitigation alternatives in each unique setting.

Recommendations:

- Implement channel restoration projects, including floodplain reconnection and enhancement, bank stabilization, and grade controls.
- In some cases, relocations may be necessary before channel restoration projects can be implemented.
- Additional or enhanced hydraulic models are necessary.

5.3 Levee Enhancement

The proposed levee enhancement at East Branch was assessed for practicality and effectiveness. This assessment is described in more detail in Section 4.6 of this report.

The most significant variables that affect flooding in East Branch are the relative magnitude of the flood peaks on the EBDR and Beaver Kill and their arrival time. These two rivers are comparable in size and can have profound tailwater controls on one another. The construction of FEMA's one-dimensional models of EBDR and Beaver Kill are not well suited to assess this dynamic, which is why MMI developed a two-dimensional model of this confluence. The Pepacton Reservoir serves to both attenuate the peak discharge and retard the arrival time of the flood wave peak on the EBDR; hydraulic modeling indicates that the East Branch levee would otherwise have overtopped during past flood events.

In addition to FEMA's requirements for levee accreditation, it is recommended that the proposed upgrades to the East Branch levee be designed to account for future flood flows plus an additional factor of safety as well as the dynamic interactions between the EBDR and Beaver Kill. This may result in more than the minimum of 3 feet of freeboard above the effective BFE.

Sometimes, for any combination of reasons, a levee is the only practical flood mitigation strategy for a community. In these cases, it is absolutely critical for all residents who are protected by a levee or berm, whether accredited by FEMA or not, to understand that every levee can overtop, and every levee can fail, and that they must remain diligent and prepared. Complacency can be deadly, and in some cases, the consequences of levee failure can be far worse than if it did not exist to begin with. In the event of a flood, the most prudent action for residents is to behave as if there were no levee and evacuate the protected area until waters recede.

Recommendations:

- Improved levee must meet FEMA accreditation requirements in order to be modeled and mapped as a flood control levee.

5.4 Replacement of Undersized Bridges

Overall, most bridges over the EBDR are adequately sized, and many do not contribute to backwater flooding except in the most extreme events. This is no doubt in some part a product of the river's prolific history of flooding; undersized bridges simply did not last. However, modeling indicates that several bridges may pressurize in severe floods, which may enhance the potential for scour damage. Many other bridges will have their approach roadways overtopped. This can provide valuable relief to the bridge but leaves the route impassable and often damaged.

For this reason, it is critical for residents to heed flood warnings and evacuation recommendations; rescue operations can be extremely hazardous to both evacuees and first responders alike and are often avoidable.

Depositional bars are omnipresent in the slack waters downstream of bridge piers. Replacement bridges should seek to minimize the number of piers to discourage aggradation that reduces the available hydraulic opening.

When bridges are replaced, remove all substructural or foundational elements that may impede, constrict, or otherwise deleteriously impact the conveyance of flood flows. Examples include relic abutments that continue to contract flood flows or pier bases and pile caps that can foster sediment aggradation in the slack waters they create.

Upon visual inspection, many bridges and culverts on tributary streams appear undersized, and anecdotal reports of backwater flooding, roadway and bridge deck overtopping, and sediment or debris jamming confirm these observations. In some cases, this is also reflected in FEMA modeling from the 1970s and 1980s, although stream alignments have changed, and a number of bridges have been replaced since that time. Quantitative recommendations are not possible without up-to-date hydraulic modeling of tributary streams; however, it is recommended that all new bridge and culvert crossings be designed to adhere to or exceed current applicable requirements and guidelines from NYSDOT and NYSDEC.

Roadway improvements and stream restorations should seek to minimize the number of stream crossings where possible or practical. Hydraulically adequate stream crossings can be costly to design and construct, especially in settings with such dynamic sediment transport conditions. To improve infrastructure and transportation network resiliency, reducing the total number of bridges by relocating roads can be more efficient than replacing multiple bridges. This should be considered where appropriate.

As discussed in Section 2.3: Hydrology, estimated flood flows on the EBDR have increased considerably over recent decades. It is therefore recommended that a new hydrologic analysis of flood flows on the river be performed prior to future bridge replacements to ensure that structures are adequately sized. The most modern accepted future flow or climate change scenario estimates should be applied to accommodate the bridge's design life.

5.5 Operation of Pepacton Reservoir

As detailed in Section 4.1 of this report, the Pepacton Reservoir provides flood mitigation benefits to downstream communities on the EBDR, despite the fact that it is not managed exclusively for flood control. These benefits are highly variable, depending both on downstream distance from the reservoir and void at the inception of the flood event. While ultimately responsible to the DRBC for its operations, it may be possible to enhance the dam's flood control capabilities if release capacity were increased, which would facilitate more dynamic void management. There may also be ancillary benefits to the entire Delaware River.

Recommendations:

- It is recommended that NYCDEP and DRBC explore the feasibility of upgrading the Pepacton Reservoir's outlet works to meet applicable low-level drain and impoundment evacuation requirements per NYSDEC. In addition to bringing the dam up to modern safety standards, this could also facilitate far more dynamic void management strategies as well as the ability to perform more geomorphologically significant conservation releases.

5.6 Updated FEMA Hydraulic Models

Many areas in the EBDR basin are at risk of flooding damages from the river's many tributary streams. Most of these were last modelled in the 1970s and 1980s using the antiquated HEC-2 software; many have never been modeled. It is recommended that new modeling of these tributaries be developed to reflect current hydraulic and hydrologic conditions. These updated models may be used to devise flood mitigation strategies that address the specific priorities of individual communities.

Recommendations:

- Seek updated, enhanced hydraulic models for tributaries to the EBDR.
- Maintain and update hydraulic modeling to reflect changes such as bridge replacements, flood mitigation projects, or updated flood hydrology. When appropriate, seek Letters of Map Change (LOMC) through FEMA to ensure the SFHA is accurately represented and residents have adequate coverage through the NFIP.

5.7 Sediment Management

Tributary sediment loading can be reduced by stabilizing mass failures and installing appropriate grade control structures to prevent further channel incision and arrest active headcuts. The larger sediments delivered by these tributaries cannot be easily transported by the EBDR, so where aggradation threatens property and infrastructure, it is generally more effective to intercept sediments or stabilize their source farther upstream. In some cases, sediment traps, with comprehensive operation plans, may be appropriate. Proactive approaches are far more effective than reactive responses such as dredging.

Local representatives often report a sentiment that dredging will alleviate flooding along the EBDR. Dredging and debris removal are often the first, and occasionally misguided, response to flooding. Dredging for flood control is usually a futile endeavor; the source of the issue is not addressed, and more often than not, the very next flood will cause the very same problem. Overwidening or overdeepening through dredging can initiate instability (including bed and bank erosion), may foster poor sediment transport, and will not necessarily provide significant flood mitigation. Sediment removal can further isolate a stream from its natural floodplain, disrupt sediment transport, expose erodible sediments, cause upstream bank or channel scour, and encourage additional downstream sediment deposition. Improperly dredged stream channels often show signs of severe instability, which can cause larger problems after the work is complete. Such a condition is likely to exacerbate flooding on a long-term basis.

A sound sediment management program sets forth standards to delineate how, when, and to what dimensions sediment excavation should be performed. Sediment excavation requires regulatory approvals as well as budgetary considerations to allow the work to be funded on an ongoing or as-needed basis as prescribed by the standards to be developed. Conditions in which active sediment management should be considered for the purpose of infrastructure protection or at bridge openings where hydraulic capacity has been compromised.

In cases where sediment excavation in the stream channel is necessary, a methodology should be developed that would allow for proper channel sizing and slope. The following guidelines are recommended:

1. Maintain the original channel slope and do not overly deepen or widen the channel. Excavation should not extend beyond the channel's estimated bankfull width unless it is to match an even wider natural channel.

2. Sediment management should be limited in volume to either a single flood's deposition or to the watershed's annual sediment yield in order to preclude downstream bed degradation from lack of sediment. Annual sediment yields vary, but one approach is to use a regional average of 50 cubic yards per square mile per year unless a detailed study is made.

3. Excavation of fine-grained sediment releases turbidity. Best available practices should be followed to control sedimentation and erosion.

4. Sediment excavation requires regulatory permits. Prior to initiation of any in-stream activities, NYSDEC should be contacted, and appropriate permitting should be obtained.

5. Disposal of excavated sediments should always occur outside of the floodplain. If such materials are placed on the adjacent bank, they will be vulnerable to remobilization and redeposition during the next large storm event.

6. No sediment excavation should be undertaken in areas where aquatic-based rare or endangered species are located.

5.8 Riparian Buffers

The Natural Resource Conservation Service (NRCS) (2016) defines a riparian buffer as, "a corridor of trees and/or shrubs planted adjacent to a river, stream, wetland or water body." The definition continues to note that the width of the buffer and the distance of the buffer from the waterbody are essential characteristics determining the functioning of the buffer.

The benefits provided by riparian buffers to their adjacent waterbodies have been well documented. These benefits can include those to the physical stability of the stream as well as those to habitat and water quality.

The physical benefit of a riparian buffer to a stream has been shown to include increased stability, reduced stream bank erosion, and reduced channel migration. Scientific studies have found that intertwining roots within a streambank can increase streambank strength, increase resistance to erosion caused by high flows, and provide greater channel stability (Sweeney and Newbold, 2014). One study found that following major floods bank erosion was 30 times more prevalent on stream bends without forests than those with forests (Beeson and Doyle, 1996). Other studies have also shown that forested stream reaches exhibit slower channel migration and thus provide more stability than deforested channels (Hession et al., 2003; Allmendinger et al., 2005). The NRCS (2016) notes that stabilized stream banks also help maintain the geometry of the stream, including characteristics such as the meander length and profile.

The dimensions of the riparian buffer have been shown to play an important role in the functioning of the buffer. Burckhardt and Todd (1998) found that streamside forests with widths of around 10 m (approximately 33 feet) provide some protection from channel migration. Similarly, Zaimes et al. (2006) found bank erosion was lowered significantly by the presence of a streamside forest approximately 33 feet wide along reaches within an agricultural landscape. Sweeney and Newbold (2014) found that the influence of vegetation appears to be greatest when the roots extend to the toe of banks (Thorne, 1990; Anderson et al., 2004). Otherwise, the stream bank is susceptible to erosion from the stream as it flows. According to the NRCS Practice Standard for Riparian Forest Buffers, the minimum width should be at least 35 feet from the top of the bank.

In terms of the vegetation making up the riparian buffer, the NRCS recommends utilizing native species, if available, that are the following:

- Adapted to the soil and climate of the planting site
- Water-loving or water-tolerant species and tolerant of extended periods of flooding (depending on the width of the planting and distance from the stream banks)
- Moderate to aggressive root and crown spread to occupy the site quickly and provide adequate litter fall
- Resistant to pests and herbicides (if adjacent to farmland)

The benefits of riparian buffers to habitat include providing food and cover for wildlife and shade that helps to lower water temperatures. Buffers can also increase habitat diversity in several ways; the addition of large woody debris to a stream provides habitat to a range of species, and a reduction in sedimentation helps prevent silt from covering large rocks or stones and from filling pools in the streambed, both of which serve as habitat. In terms of improvements to water quality, buffers have been shown to protect water resources from pollutants in surface runoff, such as sediment and nutrients. Vegetated riparian buffers serve to slow water velocity, thus allowing sediment to settle out of the runoff water. The nitrogen and phosphorus attached to the sediment settle out of the surface runoff as well. To a lesser extent, dissolved nitrogen and phosphorus and other pollutants can be sequestered, degraded, and processed in the riparian buffer.

5.9 Road Closures

Approximately 75 percent of all flood fatalities occur in vehicles. Shallow water flowing across a flooded roadway can be deceptively swift and wash a vehicle off the road. Water over a roadway can conceal a washed-out section of roadway or bridge. When a roadway is flooded, travelers should not take the chance of attempting to cross the flooded area. It is not possible to tell if a flooded road is safe to cross just by looking at it.

One way to reduce the risks associated with the flooding of roadways is their closure during flooding events, which requires effective signage, road closure barriers, and consideration of alternative routes.

According to FEMA modeling, historical documentation, and anecdotal reporting, flood-prone roads exist throughout the EBDR basin. Flooding can occur from the EBDR, tributary streams, or both. In many cases, small, unnamed tributaries and even roadside drainage ditches frequently cause washouts or other significant damage to roadways, culverts, and bridges. Drainage issues and flooding of smaller tributary streams are generally not reflected in FEMA modeling, so local public works and highway departments are often the best resource for identifying priority areas and repetitively damaged infrastructure.

5.10 Stormwater Runoff Storage

Runoff from small, frequent rain events may be intercepted by both natural and man-made storage areas. These can be highly beneficial for water quality and may help to mitigate certain isolated or localized chronic issues with stormwater infrastructure. However, small storage areas scattered throughout the watershed are not capable of causing a meaningful reduction of peak flows in the extreme events that are the focus of this report, such as the 100-year flood. This can generally only be accomplished by very large dams or massive wetland complexes that dominate basin hydrology (e.g., Bellu et. al 2016, Watson et. al 2016, Trueheart et. al 2020).

Existing wetlands in the watershed provide a vital function by storing stormwater during floods and releasing it gradually downstream, thereby reducing peak flows. Protecting the functions and values of remaining existing wetlands is recommended. A 35.1-acre NYSDEC-regulated freshwater wetland is located along the EBDR just upstream of Corbett. Smaller wetlands occur along many of the EBDR tributaries.

5.11 Individual Property Flood Protection

A variety of measures are available to protect existing public and private properties from flood damage. While broader mitigation efforts are most desirable, they often take time and money to implement. On a case-by-case basis where structures are at risk, individual floodproofing should be explored. Property owners within FEMA-delineated floodplains should also be encouraged to purchase flood insurance under the NFIP and to make claims when damage occurs.

Communities within the EBDR basin should work to identify and remove vacant and abandoned structures to prevent future hazards. In areas where properties are vulnerable to flooding, improvements to individual properties and structures may be appropriate. Potential measures for property protection include the following:

<u>Elevation of the structure</u> – Home elevation involves the removal of the building structure from the basement and elevating it on piers to a height such that the first floor is located at least 2 feet above the level of the 100-year flood event. The basement area is abandoned and filled to be no higher than the existing grade. All utilities and appliances located within the basement must be relocated to the first-floor level or installed from basement joists or similar mechanism.

<u>Construction of property improvements such as barriers, floodwalls, and earthen berms</u> – Such structural projects can be used to prevent shallow flooding. There may be properties within the basin where implementation of such measures will serve to protect structures.

<u>Dry floodproofing of the structure to keep floodwaters from entering</u> – Dry floodproofing refers to the act of making areas below the flood level watertight and is typically implemented for commercial buildings that would be unoccupied during a flood event. Walls may be coated with compound or plastic sheathing. Openings such as windows and vents can be either permanently closed or covered with removable shields. Flood protection should extend only 2 to 3 feet above the top of the concrete foundation because building walls and floors cannot withstand the pressure of deeper water.

<u>Wet floodproofing of the structure to allow floodwaters to pass through the lower area of the structure unimpeded</u> – Wet floodproofing refers to intentionally letting floodwater into a building to equalize interior and exterior water pressures. Wet floodproofing should only be used as a last resort. If considered, furniture and electrical appliances should be moved away or elevated above the 100-year flood elevation.

<u>Performing other home improvements to mitigate damage from flooding</u> – The following measures can be undertaken to protect home utilities and belongings:

- Relocate valuable belongings above the 100-year flood elevation to reduce the amount of damage caused during a flood event.
- Relocate or elevate water heaters, heating systems, washers, and dryers to a higher floor or to at least 12 inches above the base flood elevation (if the ceiling permits). A wooden platform of pressure-treated wood can serve as the base.
- Anchor the fuel tank to the wall or floor with noncorrosive metal strapping and lag bolts.
- Install a backflow valve to prevent sewer backup into the home.
- Install a floating floor drain plug at the lowest point of the lowest finished floor.
- Elevate the electrical box or relocate it to a higher floor and elevate electric outlets.

<u>Encouraging property owners to purchase flood insurance under the NFIP and to make claims when damage occurs</u> – While having flood insurance will not prevent flood damage, it will help a family or business put things back in order following a flood event. Property owners should be encouraged to submit claims under the NFIP whenever flooding damage occurs in order to increase the eligibility of the property for projects under the various mitigation grant programs.

6.0 FUNDING SOURCES

Funding for bridge and culvert replacements and other infrastructure upgrades is often scarce in small communities. In a 2017 survey of county, city, town, and village officials in NYS conducted by Aldag et al. of Cornell University, 80 percent of responders reported that infrastructure needs contribute to local fiscal stress, and 86 percent said that fiscal stress affects local infrastructure budgeting. The consequence is that local governments that are fiscally stressed are likely to have substantial needs for infrastructure investment but must defer addressing them (NYS Comptroller, 2017). Because of this, external funding is often necessary, and a concerted effort is required to secure these grants although small local governments may not have staff available to dedicate to these endeavors.

Several funding sources may be available for the implementation of recommendations made in this report. These and other potential funding sources are discussed in further detail below. Note that these may evolve over time as grants expire or are introduced.

Emergency Watershed Protection Program (EWP)
Through the EWP program, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) can help communities address watershed impairments that pose imminent threats to lives and property. Most EWP work is for the protection of threatened infrastructure from continued stream erosion. NRCS may pay up to 75 percent of the construction costs of emergency measures. The remaining costs must come from local sources and can be made in cash or in-kind services. EWP projects must reduce threats to lives and property; be economically, environmentally, and socially defensible; be designed and implemented according to sound technical standards; and conserve natural resources.

FEMA Pre-Disaster Mitigation (PDM) Program
The PDM program was authorized by Part 203 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act (Stafford Act), 42 U.S.C. 5133. The PDM program provides funds to states, territories, tribal governments, communities, and universities for hazard mitigation planning and implementation of mitigation projects prior to disasters, providing an opportunity to reduce the nation's disaster losses through PDM planning and the implementation of feasible, effective, and cost-efficient mitigation measures. Funding of pre-disaster plans and projects is meant to reduce overall risks to populations and facilities. The PDM program is subject to the availability of appropriation funding as well as any program-specific directive or restriction made with respect to such funds.
https://www.fema.gov/pre-disaster-mitigation-grant-program

FEMA Hazard Mitigation Grant Program (HMGP)

The HMGP is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The HMGP provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. A key purpose of the HMGP is to ensure that any opportunities to take critical mitigation measures to protect life and property from future disasters are not "lost" during the recovery and reconstruction process following a disaster.

The HMGP is one of the FEMA programs with the greatest potential fit to potential projects in this LFA. However, it is available only in the months subsequent to a federal disaster declaration in the State of New York. Because the state administers the HMGP directly, application cycles will need to be closely monitored after disasters are declared in New York.
https://www.fema.gov/hazard-mitigation-grant-program

FEMA Flood Mitigation Assistance (FMA) Program

The FMA program was created as part of the National Flood Insurance Reform Act (NFIRA) of 1994 (42 U.S.C. 4101) with the goal of reducing or eliminating claims under the NFIP. FEMA provides FMA funds to assist states and communities with implementing measures that reduce or eliminate the long-term risk of flood damage to buildings, homes, and other structures insurable under the NFIP. The long-term goal of FMA is to reduce or eliminate claims under the NFIP through mitigation activities.

The Biggert-Waters Flood Insurance Reform Act of 2012 eliminated the Repetitive Flood Claims (RFC) and Severe Repetitive Loss (SRL) programs and made the following significant changes to the FMA program:

- The definitions of repetitive loss and SRL properties have been modified.
- Cost-share requirements have changed to allow more federal funds for properties with RFC and SRL properties.
- There is no longer a limit on in-kind contributions for the nonfederal cost share.

One limitation of the FMA program is that it is used to provide mitigation for *structures* that are insured or located in SFHAs. Therefore, the individual property mitigation options are best suited for FMA funds. Like PDM, FMA programs are subject to the availability of appropriation funding as well as any program-specific directive or restriction made with respect to such funds.
http://www.fema.gov/flood-mitigation-assistance-grant-program

NYS Department of State

The Department of State may be able to fund some of the projects described in this report. In order to be eligible, a project should link water quality improvement to economic benefits.

NYS Department of Environmental Conservation – Municipal Waste Reduction and Recycling (MWRR) Program

The NYS Department of Environmental Conservation (DEC) administers MWRR funding to local government entities for waste reduction and recycling projects. The overall goal of this funding program is to assist municipalities in expanding or improving local waste reduction and recycling programs and to increase participation in those programs.

The MWRR state assistance program can help fund the costs of the following:

- Capital Investment in Facilities and Equipment

Eligible projects are expected to enhance municipal capacity to collect, aggregate, sort, and process recyclable materials. Recycling equipment includes structures, machinery, or devices providing for the environmentally sound recovery of recyclables including source separation equipment and recyclables recovery equipment.

U.S. Army Corps of Engineers (USACE)

The USACE provides 100 percent funding for floodplain management planning and technical assistance to states and local governments under several flood control acts and the Floodplain Management Services Program (FPMS). Specific programs used by the USACE for mitigation are listed below.

- Section 205 – Small Flood Damage Reduction Projects: This section of the 1948 Flood Control Act authorizes the USACE to study, design, and construct small flood control projects in partnership with nonfederal government agencies. Feasibility studies are 100 percent federally funded up to $100,000, with additional costs shared equally. Costs for preparation of plans and construction are funded 65 percent with a 35 percent nonfederal match. In certain cases, the nonfederal share for construction could be as high as 50 percent. The maximum federal expenditure for any project is $7 million.

- Section 14 – Emergency Stream Bank and Shoreline Protection: This section of the 1946 Flood Control Act authorizes the USACE to construct emergency shoreline and stream bank protection works to protect public facilities such as bridges, roads, public buildings, sewage treatment plants, water wells, and nonprofit public facilities such as churches, hospitals, and schools. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is $1.5 million.

- Section 208 – Clearing and Snagging Projects: This section of the 1954 Flood Control Act authorizes the USACE to perform channel clearing and excavation with limited embankment construction to reduce nuisance flood damages caused by debris and minor shoaling of rivers. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is $500,000.

- Section 206 – Floodplain Management Services: This section of the 1960 Flood Control Act, as amended, authorizes the USACE to provide a full range of technical services and planning guidance necessary to support effective floodplain management. General technical assistance efforts include determining the following: site-specific data on obstructions to flood flows, flood formation, and timing; flood depths, stages, or floodwater velocities; the extent, duration, and frequency of flooding; information on natural and cultural floodplain resources; and flood loss potentials before and after the use of floodplain management measures. Types of studies conducted under FPMS include floodplain delineation, dam failure, hurricane evacuation, flood warning, floodway, flood damage reduction, stormwater management, floodproofing, and inventories of flood-prone structures. When funding is available, this work is 100 percent federally funded.

In addition, the USACE provides emergency flood assistance (under Public Law 84-99) after local and state funding has been used. This assistance can be used for both flood response and post-flood response. USACE assistance is limited to the preservation of life and improved property; direct assistance to individual homeowners or businesses is not permitted. In addition, the USACE can loan or issue supplies and equipment once local sources are exhausted during emergencies.

Other Potential Sources of Funding

New York State Grants
All New York State grants are now announced on the NYS Grants Gateway. The Grants Gateway is designed to allow grant applicants to browse all NYS agency anticipated and available grant opportunities, providing a one-stop location that streamlines the way grants are administered by the State of New York.
https://grantsmanagement.ny.gov/

Bridge NY Program
The Bridge NY program, administered by NYSDOT, is open to all municipal owners of bridges and culverts. Projects are awarded through a competitive process and support all phases of project development. Projects selected for funding are evaluated based on the resiliency of the structure, including such factors as hydraulic vulnerability and structural resiliency; the significance and importance of the bridge including traffic volumes, detour considerations, number and types of businesses served and impacts on commerce; and the current bridge and culvert structural conditions.
https://www.dot.ny.gov/BRIDGENY.

Private Foundations
Private entities such as foundations are potential funding sources in many communities. Communities will need to identify the foundations that are potentially appropriate for some of the actions proposed in this report.

In addition to the funding sources listed above, other resources are available for technical assistance, planning, and information. While the following sources do not provide direct funding, they offer other services that may be useful for proposed flood mitigation projects.

Land Trust and Conservation Groups
These groups play an important role in the protection of watersheds, including forests, open space, aquatic ecosystems, and water resources.

Communities will need to work closely with potential funders to ensure that the best combinations of funds are secured for the proposed alternatives and for the property-specific mitigation such as floodproofing, elevations, and relocations. It will be advantageous for the communities to identify combinations of funding sources in order to reduce its own requirement to provide matching funds.

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